Robert Millikan (top center) on the steps of Ryerson Laboratory, U. of Chicago, 1908. Other colleagues (L-R): A. A. Michelson, Carl Kinsey, Henry G. Gale

ROBERT A. MILLIKAN
Oil Drop Experiment Notebooks

NOTEBOOK ONE:
October 1911-March 1912

PART 1 OF 3
From page 1 to page 39

ARCHIVES
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

Abstract

Robert A. Millikan (1868-1953) began his experiments to measure the charge on the electron, e, in 1907. The experiments were performed in Ryerson Laboratory at the University of Chicago, where Millikan was professor of physics. For this work, and for work on the photoelectric effect, Millikan was awarded the Nobel Prize in physics in 1923.

Millikan gives his own account of the electron charge determination in his published autobiography in the chapter titled "My Oil-Drop Venture (e)" (Robert A. Millikan, *The Autobiography of Robert A. Millikan*, New York, 1950). With the aid of graduate students Louis Begeman, Harvey Fletcher, and J. Y. Lee, Millikan devised the method of measuring the rate of fall of a single electrically charged oil drop under the forces of gravity and electricity. From 1909 until the spring of 1912, Millikan reports, he spent every available moment in the laboratory on his oil-drop experiment. His first comprehensive, though to some extent preliminary, results were published in September 1910 in the journal *Science* as "The Isolation of an Ion, a Precision Measurement of Its Charge, and the Correction of Stokes' Law," *Science* 32: 436-448. He soon became embroiled in a controversy with the Viennese physicist Felix Ehrenhaft, who claimed to have found much smaller electric charges. Millikan went back to work on a new

set of experiments. By the spring of 1912 he had collected the data for what he termed "the final, absolute determination of the numerical value of the electron" (*Autobiography*, p. 84). Results were published in August 1913 in "On the Elementary Electrical Charge and the Avogadro Constant," *Physical Review* 2: 109-43. This last, definitive set of experiments were recorded in the only two lab notebooks which Millikan preserved among his papers. These two notebooks are presented here in facsimile. They cover the period from October 1911 through April 1912 and contain what Millikan himself considered his conclusive, historic work on this problem.

For an analysis of Millikan's notebooks and a defense of his experimental method, see the article by David Goodstein, "In Defense of Robert Andrews Millikan," published in *American Scientist* 89/1 (Jan-Feb. 2001): 54. http://www.americanscientist.org/issues/num2/2001/1/in-defense-of-robert-andrews-millikan/1

Administrative information

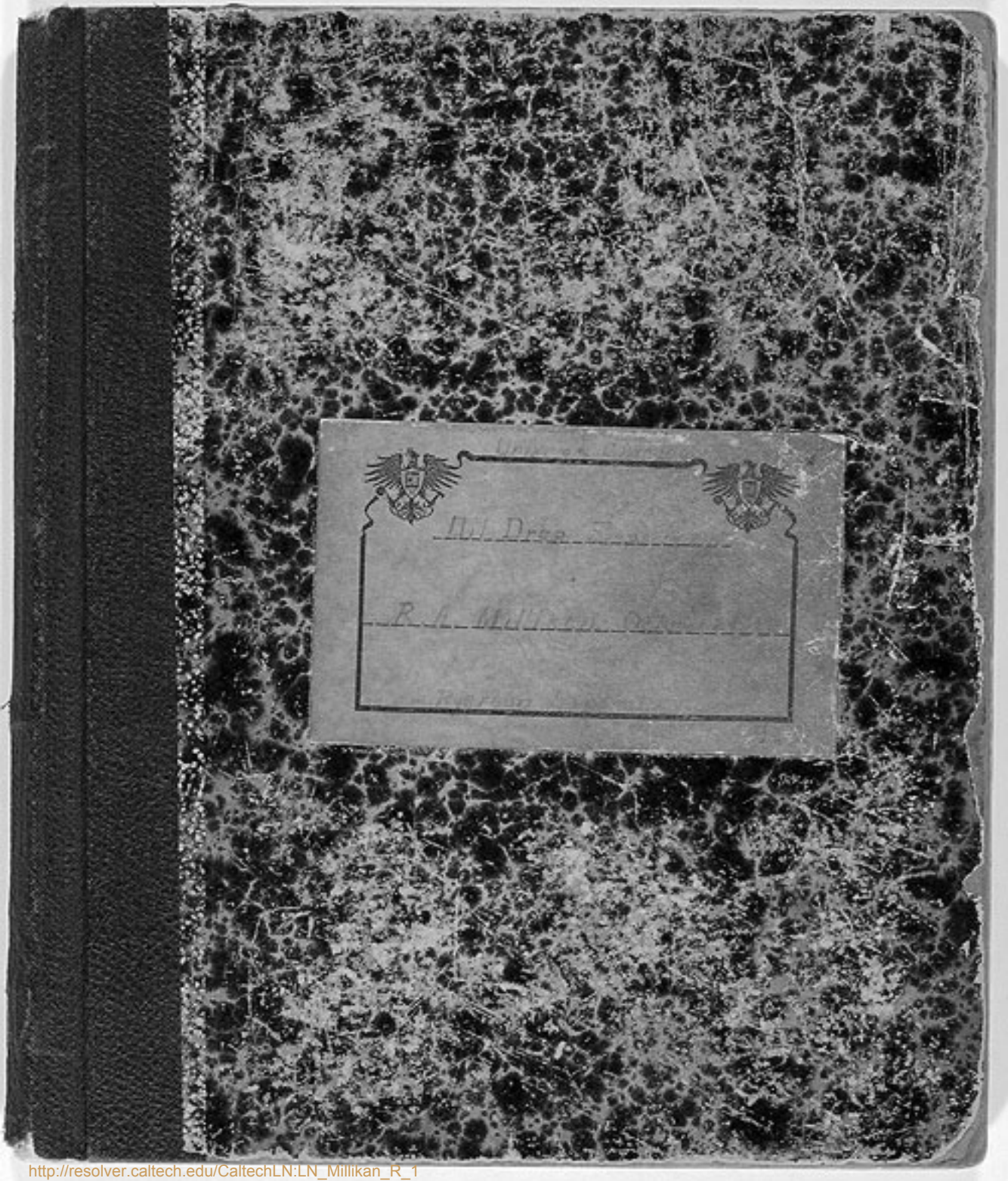
Copyright Notice

Preferred citation

Robert A. Millikan Oil Drop Experiment Notebooks. Lab Notes Online. California Institute of Technology Archives. Retrieved [supply date of retrieval] from the World Wide Web:
http://resolver.caltech.edu/CaltechLN:LN_Millikan_R_1

Contact information

Archives, California Institute of Technology
Mail Code 015A-74
Pasadena, CA 91125
Phone: (626) 395-2704 Fax: (626) 793-8756
Email: archives@caltech.edu



Thermometer Readings and Corrections—

Standard	Beckman	$\frac{1}{10}°$ small stem (.15° low)	$\frac{1}{10}°$ large stem
22.79	1.76		
22.81	1.78		
23.00	1.97	22.85	22.95 (?)

Corrections to Standard Thermometer.

	0	.1	.2	.3	.4	5	6	7	8	9
22°	-0.025	-0.025	-0.025	-0.025	-0.024	-0.024	-0.024	-0.023	-0.023	-0.023
23°	-0.023	-0.022	-0.022	-0.022	-0.022	-0.022	-0.021	-0.021	-0.021	-0.021
24°	-0.021	-0.020	-0.020	-0.020	-0.020	-0.020	-0.020	-0.020	-0.019	-0.019

605	14.0
695	16.2
725	18.6
750	18.0
800	16.0
805	15.8
810	15.6
815	15.2
820	14.8
825	14.5
830	14.1
835	13.6
840	13.2
845	13.0
850	12.9
855	12.8
860	12.8
870	12.9
880	13.3
896	13.8
900	14.4

590	12.8
555	8.0
540	6.5
447	0.0

Density of Clock oil

10/24/11.

By R. A. Millikan

Oil & bottle

Rest point 10.9 Wt. 20.171 Sens. 2 div per mg. temp 18°C

Bottle alone

Rest point 10.6 Wt. 10.918

Water + Bottle

Wt 20.933 ——→ ten 18° C

Wt of oil alone = 20.171 − 10.918 = 9.253

Relative Wts = .9239

Wt of water alone = 20.933 − 10.918 = 10.015

Absolute WT = .9239 × .99867 = .9230

(.9656 × .9941 = .9597)

Determin. by P. J. Parrale, 10/21/11.

Density at 14°C = 0.9252
" " 22°C = 0.9202

} ∴ Mean change per degree C. = .000625

Note:-

A correction of .004% per degree C. must be applied for change in viscosity of air. 23°C. is the temp. where no correction is needed. Below 23°, the correction must be subtracted.

A correction of .0004% per degree must be applied for change in density of air. This correction can be applied with 23° as the point of no correction. It is also minus when the temp. is below 23°.

∴ Correction for (change of viscosity + change of density) = .0045% per degree C.

Saturday — 10/28/11. 3:30 P.M. to 4:30

t = 15.8 p = 20.51

Volts

840 + 13.2
828 + 14.2
818 + 14.9
843 + 13.0
845 + 13.0
837 + 12.9
5011 + 81.2
81
5092
At Beginning

G	F
Lower field	
19.6	
19.1	
19.4	
19.6	
19.4	
19.6	
19.3	
Middle of field	
19.4	
19.3	
19.4	
19.3	
19.5	
19.2	
19.6	
19.4	
19.3	(8.2)'
19.8	(10.2)''
19.6	
19.6	
19.6	
19.6	
19.4	(21.2)^{IV}
19.3	(20.7)
	(43.5)^{V}
19.8	(43.2)^{V}
	(8.6)'
Upper field	
19.8	(21.2)^{IV}
19.4	(21.2)^{IV}
19.5	
19.3	(14.2)'''
19.7	(21.2)^{IV}
19.6	(44.2)^{V}
19.6	(21.0)^{IV}
Mean = 19.484	(75.0) Even with 9.5 for one divis.
	(43.6)^{V}

Volts 5052

Weighted mean volts over this period = 5052

5092
5039
53

Volts = 5052
Log 3.7035

Volts
5039
At End.

Drop changed from Neg. to Pos. about middle of observation.

7.7157 / 1.1523 / 3.5634 — 7.7157 / 1.3336 / 3.3949 — 7.7157 / 1.6401 / 3.0733 — 7.7157 / 2.7202 / 5.9935

7.7157 / 1.3137 / 3.4020 — 7.7157 / 3.4638 / 3.3443 — 7.7157 / 1.0052 / 3.7101

$$V_1 = \frac{.5232}{19.484} = 0.02685$$

$$V_2' = \frac{.5232}{8.2} = 0.0638 \quad .02685 \quad 3|\underline{0.09065} \quad 0.01275$$

$$V_2'' = \frac{2K}{10.2} = 0.0513 \quad .02685 \quad 6|\underline{0.07815} \quad 0.01303$$

Means

(8.2)$'_2$

$$V_2''' = \frac{K}{14.2} = 0.03685 \quad .02685 \quad 5|\underline{0.06370} \quad 0.01274$$

(10.2)$''_1$

(14.2)$'''_1$

$$V_2^{IV} = \frac{K}{21.08} = 0.02482 \quad .02685 \quad 4|\underline{.05167} \quad 0.01292$$

$$V_2^{V} = \frac{K}{43.7} = 0.01201 \quad .02685 \quad 3|\underline{0.03886} \quad 0.01295$$

— mean = 0.012926

(21.83)$^{IV}_6$

(43.7)$^{V}_4$

$$V_2^{VI} = \frac{K}{525} = 0.000997 \quad .02685 \quad 2|\underline{0.025653} \quad 0.01292?$$

where K = .5232

(525.0)$^{VI}_1$

Explanation:- (10.2)$''_1$ means the mean of 1 values of the 2nd speed and (43.7)$^{V}_4$ means the mean of 4 values of the 5th speed.

Log $V_1 + V_2$ = $\bar{2}$.1115
$\bar{1}$.2145
$\bar{3}$.1983
−6.5243
3.7035
−10.8208

6.619
.214
6.405 = e 10^{-10}
Log = −10.8132

$e^{2/3}$	l	a	l/a
−10.8132	−4.8548	−16.4327	−5.5426
2	1.3120	2.4290	−4.1512
3|−19.6264	−5.5428	3.7035	−1.3914
−7.8755		−14.5652	
		−2.1115	
		3|−12.4537	
		−4.1512	
75.05 × 10^{-8}	.0000349	.0001417	.2463

Density of clock oil

10/24/11

By R. A. Millikan

Oil & bottle

Rest point 10.9 Wt. 20.171 Sens. 2 div per mg. temp 18°C

Bottle alone

Rest point 10.6 Wt. 10.918

Water + Bottle

Wt 20.933 ——→ temp 18° C

Wt of oil alone = 20.171 − 10.918 = 9.253

Relative Wts = .9239

Wt of water alone = 20.933 − 10.918 = 10.015

Absolute WT = .9239 × .99867 = .9230

(.9239 × .99867 = 9239 + 9241 + 14647 = .9230)

Determin. by P. J. Farrall, 10/31/11.

Density at 14°C = 0.9252
" " 22°C = 0.9202
∴ Mean change per degree C. = .000625

Note:-

A correction of .004% per degree C. must be applied for change in viscosity of air. 23°C. is the temp. where no correction is needed. Below 23°, the correction must be subtracted.

A correction of .004% per degree must be applied for change in density of air. This correction can be applied with 23° as the point of no correction. It is also minus when the temp. is below 23°.

∴ Correction for (change of viscosity + change of density) = .0045% per degree C.

#26

Oct 26 11/20/11 — 4:30 P.M. to 5:40

Positive — Neutral Color

$t = 16.0$ $p = 21.58$

At Beginning

Volts

839 + 13.4
823 + 14.6
813 + 15.4
840 + 13.2
804 + 15.8
834 + 13.6
4952 + 87.0
87
5039

weighted mean 5027 Volts

log = 3.7013

At End

827 + 14.3
821 + 14.7
812 + 15.4
840 + 13.2
780 + 17.0
834 + 13.6
4933 + 88.4
88
5021

	G	F
90	8.7	
90	8.9	
90	8.6	
80	8.6	
80	9.0	
82	8.4	
	8.6	
81	8.7	
81	8.8	
81	9.0	
81	8.8	
81	9.0	
83	8.9	
80	9.0	
80	8.9	
81	9.0	
82	8.7	
	8.8	
80	9.0	12.6
81	9.0	12.5
82	8.6	28.8
		24.2
80	8.7	15.5
82		15.8
	8.8	15.6
80		15.6
83		15.6
		15.6
80	8.8	29.2
		29.0
80		28.8
		28.8
82	9.0	211.0
81		215.0
	8.9	

12.6, 12.5 → $(12.55)_2'$; 15.6 → $(15.607)_2''$; → $(29.97)_2'''$; 211.0, 215.0 → $(213.0)_2^{IV}$

weighted mean Volts = 5027 Volts

Mean = 8.82
97
Corrected 8.723

7.7187 / 0.9407 / 2.7780; 7.7187 / 1.0986 / 2.62 ; 7.7187 / 1.1973 / 2.22

1.9407 / 1.4660 / 1.2567; 7.7187 / 2.3284 / 3.3903

$V_1 = \frac{0.5232}{8.723} = 0.05998$

$V_2' = \frac{0.5232}{12.55} = 0.04170$ — .05998 — 11) 0.10168 — 0.00972

$V_2'' = \frac{K}{15.607} = 0.03353$ — .05998 — 12) 0.09351 — 0.007793

$V_2''' = \frac{K}{29.97} = 0.01806$ — .05998 — 10) 0.07799 — 0.007799

$V_2^{IV} = \frac{K}{213.0} = 0.00246$ — .05998 — 8) 0.06244 — 0.007806

mean = 0.007799

where K = .5232

$\log V_1 + V_2 = -3.8920$

$\frac{1}{2} \log V_1 = -1.3890$
-3.1983
-6.4793
3.7013
$\log e = -10.7780$

$C = (5.998 - .15)10^{-10} = 5.81 \times 10^{-10}$

log = −10.7642

(P)

Stoptonic corr
36) 240 (9
234
60
8092
= 1.14 kg

$e^{2/3}$
−10.7642
3) −19.5284
−7.6428
69.63 × 10⁻⁸

l
−4.8547
1.3890
−5.5207
.0000 3317

a
−16.4327
−2.7780
3.7013
−14.9120
−3.8920
3) −11.0200
−4.3400
.0002188

l/a
−5.5207
−4.3400
−1.1807
.1516

#27

10/28/11 – 5:45 P.M. to 6:20

Red – Positive

$t = 15.8$ $p = 22.07$

Volts
5021
at Beginning

Weighted
Mean Volts
4993 Volts

log = 3.6984

G		F
Middle of field: 15.2	151	
15.4	149	
14.7	151	
15.1	150	
14.9	149	
15.1	147	
14.9	153	
15.2	151	
Lower field: 14.9	152	
15.1	151	
15.2	151	
16.1	149	
15.2	148	
15.0	150	10.4
Upper field: 15.2	150	8.7
15.0	151	8.8
14.8	150	10.8
14.9	151	13.4
15.2	151	13.2
14.8	151	13.3
14.8	Bottom	69.4
Mean 15.033	Middle	68.8
	Top	69.3

weighted mean value = 4993 volts

$(8.75)'_2$, $(10.35)''_2$, $(13.3)'''_2$, $(18.3)^{IV}_2$, $(69.17)^{V}_2$

Volts at End
835 + 126
820 + 16.9
807 + 15.8
842 + 17.2
761 + 17.8
832 + 17.7
4895 + 89.8
89
4984

Corrected Mean = 15.011

Stop watch checks 1502 (6.½ % high)

$V_1 = \frac{0.5232}{15.011} = 0.03486$

$V_2' = \frac{0.5232}{8.75} = 0.05980$; 0.02494 ; 0.01052

$V_2'' = \frac{K}{10.35} = 0.05056$; 0.08542 ; 0.01068

$V_2''' = \frac{K}{13.3} = 0.03934$; 0.07420 ; 0.01060

$V_2^{IV} = \frac{K}{18.3} = 0.02859$; 0.06345 ; 0.01058

$V_2^{V} = \frac{K}{69.17} = 0.00757$; 0.04243 ; 0.01061

mean = 0.010597

where K = 0.5232

log $k V_1$ = −2.0252
log V_1 = −1.2911
−3.1983
−6.4946
3.6984
log e = −10.7962

$e = (6.255 - .203)10^{-10}$
$= 6.052 \times 10^{-10}$
log e = −10.7819

$e^{2/3}$	l	a	$\frac{l}{a}$
−10.7819	−4.8542	−16.4327	−5.5101
2	1.3441	−2.5425	−4.2162
3 / −14.5638	−5.5101	3.6985	−1.2939
−4.8546	.00003237	−14.6767	.1967
71.60 × 10^{-8}		−2.0252	
		3 / −12.6485	
		−4.2162	
		.0001645	

(P)

Nov 17/11

Mutiliscope (Gaertner) Focal distance 13.94 mm
Tem 21.7

G.	F
22.6	50.2
22.6	50.4
22.4	34.4
22.6	34.4
22.55	

P = atmos. = 74.0 cm.

$V_1 = \frac{13.94}{22.55} = .06181$

$V_2 = \frac{13.94}{50.3} = .02771$

$V_3 = \frac{13.94}{34.4} = .04052$

.06181
.08952
.01279

.06181
8/.10233
.01279

Volts
837 + 13.6
818 + 15.0
828 + 14.0
803 + 16.0
774 + 17.3
832 + 13.8
4892 + 89.6
90
4982

.1443
1.5366
1.6077

log(V₁+V₂) = 1.1069
½ log V₁ = 1.3956
-3.1983
-6.7008
3.6974
-9.0034

Log V₁+V₂ = 2.9519
½ log V₁ - 1.3956
3.1983
5.5458
3.6974
-9.8484

70.54

8.025 (10⁻⁹)
.047
7.978 · 10⁻⁹

Nov. 18, 1911.

{18 small divisions, starting from 2nd long division at bottom of field}

$t = 18.0$ °C.
$p = 73.95$ cm.

G	F			
17.0	5.9			
17.2				
17.1		→ 8.83	0.1048 / 1.2287 / $\bar{2}$.8761	$V_1 = \frac{1.273}{16.93} = 0.07518$
16.9	8.6			
16.9	9.0		0.1048 / 0.9460 / $\bar{1}$.1588	$V_2 = \frac{1.273}{8.83} = 0.14410$; .07518; 0.21928 ÷ 39 =
17.1	9.9			
	10.3			
	10.1		0.1048 / 1.0025 / $\bar{1}$.1023	$V_2' = \frac{1.273}{10.06} = 0.1266$; .07518; 0.20178 ÷ 36 = 0.005605
	10.2			
	9.8	10.06		
16.8			0.1048 / 1.2148 / $\bar{2}$.5900	$V_2'' = \frac{1.273}{16.4} = 0.07762$; .07518; 0.15280 ÷ 27 = 0.005658
16.9	9.9			
16.8	10.2		0.1048 / 1.4713 / $\bar{2}$.6335	$V_2''' = \frac{1.273}{29.6} = 0.04300$; .07518; 0.11818 ÷ 21 = 0.005627
17.0				
17.3	16.6		0.1048 / 1.9360 / $\bar{2}$.1688	$V_2'''' = \frac{1.273}{86.3} = 0.01475$; .07518; 0.08993 ÷ 16 = 0.005621
	16.2	16.4		
16.8	16.4		0.1048 / 2.5607 / $\bar{3}$.5441	$V_2''''' = \frac{1.273}{363.7} = 0.00350$; .07518; 0.07868 ÷ 14 = 0.005620
16.7				
17.0	29.4	29.6		
17.0	29.8		0.1048 / 2.1436 / $\bar{3}$.9612	$V_2'''''' = \frac{1.273}{139.2} = 0.009145$; .07518; 0.084325 ÷ 15 = 0.005622
17.0	86.3	→ 86.3		
16.8	363.7	→ 363.7		
16.6	139.2	→ 139.2		
mean = 16.93				

weighted mean = $(V_1 + V_2)$ from last 4 readings = 0.0056225

Volts

847 + 13.0
837 + 14.5
809 + 15.7
850 + 13.3
838 + 14.5
845 + 13.0
5026 84.0
84
5110

log 5110 = 3.7084

mean = 1.273 cm
12.73 = dist between cross-hairs

log 1.273 = 0.1048

log $V_1 + V_2$ = $\bar{3}$.7449
$\frac{1}{2}$ log V_1 = $\bar{1}$.4381
= 3.1983
-6.3863
3.7084
$\overline{10}$.6779

4.3 ?

Not sure of distance 1.273

Very low Something wrong

Mon. Nov. 20, 1911.

$p = 75.22$
$t = 17.6$

Volts	G	F
849 + 13.2	45.7	37.2
842 + 13.5	45.9	
813 + 15.4	45.6	
853 + 13.5	46.1	37.4 } 37.3
836 + 14.4	46.2	
846 + 13.0	45.8	37.3
5039 + 82.0	46.4	
82	45.96	
5121 = Volts		

37.3 1.5705; 1.6624

76.1 = 17 div. 76.1

31.4 = 7 div. 1.8814

$V_1 = \frac{1.357}{45.96} = .02953$ — 0.1326 / 1.6624 / 2.4702

$V_2 = \frac{1.357}{37.3} = .03638$ / .02953 / .06591 — 0.1326 / 1.5717 / 2.5609

$V_2' = \frac{1.357}{76.1} = .01783$ / .02953 / .04736 — 0.1326 / 1.8814 / 2.2512

log 5121 = 3.7094

mean $v_1 + v_2$ = .004449

$\log(V_1 + V_2) = -3.9752$
$\frac{1}{2} \log V_1 = -1.2351$
3.1983
—
-6.4086
3.7094
—
10.6992

$e_1 = 5.002$ Very low Something wrong

found meas. of distance to pin hole did not agree with meas. to focus

dist. between cross-hairs = 1.357 cm.

Big Telescope all fitted up anew

5:30 P.M. ← 11/22/11

$t = 18.0$
$p = 75.0$
dist. = 10.23

Volts at start	G	F
848 + 13.2	9.9	19.1
840 + 13.8	10.2	19.0 } 19.025
821 + 14.7	10.1	19.0
854 + 13.5	10.1	19.0
845 + 13.3	10.1	
844 + 13.1	10.2	17.2 } 17.35
5052 + 81.6	10.1	17.5
82	9.9	58.0 → 58.0
5134	10.0	83.6 → 83.6
	10.1	145.0 → 147.1
log 5134 = 3.7104	10.4	147 = time for 5.000
	9.9	148.4
	10.0	56 time for V_2
	10.0	
	10.2	
	9.9	
	10.1	
	10.1	
	9.9	

Mean = 10.053, .053 Stopwatch correction, 10.000

0.0098 / 1.0000 / 7.0098

$V_1 = \frac{1.023}{10.000} = 0.1023$

0.0098 / 1.2793 / 2.7305

$V_2 = \frac{1.023}{19.025} = 0.05376$, 1023, 0.15606 ÷ 30 = 0.005202

0.0098 / 1.2392 / 2.7706

$V_2' = \frac{1.023}{17.35} = 0.05897$, 1023, 0.16127 ÷ 31 = 0.005202

0.0098 / 1.7634 / 2.2464

$V_2'' = \frac{1.023}{58.0} = 0.01765$, 1023, 0.11995 ÷ 23 = 0.005215

0.0098 / 1.9222 / 2.0876

$V_2''' = \frac{1.023}{83.6} = 0.01224$, 1023, 0.11454 ÷ 22 = 0.005206

Mean = 0.005206

0.0098 / 3.1676 / 3.5422

$V_2'''' = \frac{1.023}{147.1} = 0.006954$, 10230, 21 | 0.109254, 0.005202

$\log(V_1 + V_2) = \bar{3}.7165$
$\frac{1}{2} \log V_1 = \bar{1}.5049$
-3.1983
—
-6.4197

-6.4198
3.7104
—
-16.7094

$e = 5.121$
115
$e = 5.006$

Wednes – 11/23/11 → 4:15 P.M.

4:44 P.M.

Volts	G	F
855+13.5	16.2	12.2
849+13.2	15.9	12.3
835+14.4	16.2	
861+12.9	16.0	20.2
854+13.5	16.0	100.2
852+13.5	16.2	
5106+80.0	16.083 = Mean	
80		
5186		

log 5186 = 3.

12.25

$t = 17.5$ $\quad p = 75.0$ $\quad dist = 10.23\ mm$

$V_1 = \frac{1.023}{16.083} = .06362$

$V_2 = \frac{1.023}{12.25} = .08352$ $\quad 6362$ $\quad .14714$

$V_2' = \frac{1.023}{20.2} = .05065$ $\quad 6362$ $\quad .81427 \div 17 = .006722$

$V_2'' = \frac{1.023}{100.2} = .01021$ $\quad 6362$ $\quad .07383 \div 11 = .006712$

mean = .006717

$\log V_1 + V_2 = \bar{3}.85291$

$2 \log V_1 = -1.4018$

3.1983

-6.4272

3.7148

10.7124

$e = 5.158$

5.030

11/24/11 → 5:10 P.M.

5:25 P.M.

Volts	G	F
850+13.2	35.2	25.7
844+13.4	35.2	25.2
827+14.0	35.4	49.4
857+13.2	35.2	49.8
848+13.1	35.2	50.0
846+13.1	35.4	147. = 5 small divisions
5072+80.0	35.267 = Mean	
80		
5157		

log 5157 = 3.7124

$t = 18.3$ $\quad p = 75.0$ $\quad dist = 10.23$

$V_1 = \frac{1.023}{35.267} = 0.02901$

$V_2 = \frac{1.023}{25.7} = \frac{0.02901}{0.039941}$ $\quad 0.07852$

$V_2' = \frac{1.023}{25.245} = \frac{0.02901}{0.04019}$ $\quad 0.06920 \div 7 = .009885$

$V_2'' = \frac{1.023}{49.867} = \frac{0.02901}{0.02051}$ $\quad 0.04952 \div 5 = .009904$

$V_2'' = \frac{1.023}{147 \times 16} = \frac{1.023}{2352} = \frac{0.02901}{0.000434\,8}$ $\quad 0.029444\,5 \div 3 = .009815$

0.0099 / 1.5473 / 3.4625

0.0098 / 1.3160 / 3.6938

0.0098 / 1.4057 / 3.6041

0.0098 / 1.6979 / 2.3179

0.0098 / 3.3715 / 7.6383

$\log(V_1 + V_2) = \bar{3}.9958$

$\frac{1}{2}\log V_1 = \bar{1}.2318$

3.1983

-6.4254

3.7124

-10.7130

$e = 5.165$ correction

$.107$

$e = 5.057$

Thurs - 11/23/11 5:10 P.M.

$t = 20.8°$

$P = 75.05$

Volts	ad 5:100	G	F
853 + 135		16.8	15.6 → 15.6
855 + 135		16.8	12.9 → 12.9
829 + 140		16.6	39.1 → 39.03
860 + 135		17.0	53.0
851 + 135		16.9	52.2 } 52.6
852 + 135		16.6	39.0
5100 + 815		17.0	26.0
815		16.6	25.7
5185		16.8	25.5 } 25.73
		16.6	39.0
		16.8	
		16.5	
		17.0	
		16.769	

$V_1 = \frac{10.25}{16.769} = .06113$

.0107 / 1.2345 / -2.7852

$V_2 = \frac{}{12.9} = .07945$ − .06113 = .01832

.0107 / 1106 / -2.9631

$V_2' = \frac{}{39.03} = .02826$ − .06113 = .03287 ÷ 13 = .006722

.0107 / 5918 / -2.1619

$V_2'' = \frac{}{52.6} = .019485$ − .06113 = .040615 ÷ 12 = .006718

.0107 / 7210 / -2.1897

$V_2''' = \frac{}{25.73} = .03983$ − .06113 = .10096 ÷ 15 = .006731

.0107 / -2.4104 / -2.6003

mean $V_1 + V_2 = .006724$

$\log V_1 + V_2 = \bar{3}.8277$

$\frac{1}{2}\log V_1 = \bar{1}.3931$

3.1983

-6.4191

3.7142

10.7059

5.080 / 5.6

$e_1 = 5.024$

29. low

11/23/11 — 5:40 P.M.

$t = 21.5$
$P = 75.05$

Volts at 5:30	G	F
850+	12.8	
851+	12.8	
820+	12.8	
860+	12.4	
847+	12.8	
849+	12.8	
5077	12.8	
	12.8	
	13.0	
	12.8	
	13.0	12.4
	13.2	17.2
	12.9	17.4
	13.1	24.3
	12.9	24.5
	12.9	24.3
	12.8	
	12.8	
	12.~~942~~	
	12.80	

Volts at 6:00
847+
845.+
818+
858+
843.+
848+
5183.

.0107
1109
-2.8998

$v_1 = \frac{1.025}{12.81} = .08194$

.0107
2360
-2.7727

$v_2 = \frac{1.025}{17.3} = .05925$
.08194
.14129 ÷ 24 = .005805

.0107
3897
-2.6210

$v_3 = \frac{1.025}{24.53} = .04178$
8194
.1237 2 ÷ 21 = .005803

mean = .005804

$\text{Log } v_1+v_2 = \bar{3}.7636$
$\frac{1}{2.11}v_1 = \bar{1}.4518$
3 1983
-6.4137
3.7146
-10.8996

5091
34
~~5043~~
4967

39.1 ~~m~~

Tues.- Nov. 28, 1911

t = 21.3 °C.
p = 75

Volts	G	F
823+14.6	(5) 19.0	
800+16.0	" 19.0	
791+15.6		
827+	(5) 18.8	
797+	" 18.8	
825+	" 18.8	9.0
	" 19.2	45.2
		45.1
		45.2
		45.1

Sat., Dec. 9, 1911.

$t = 24.0$
$p = 75.23$
dist. in between cross-hairs = 1.022 cm.

Volts	G	F
838. + 13.4	(3) 26.6	
	(5) 26.4	
840 + 13.2	(3) 26.2	11.1
826 + 14.4		19.8
853 + 12.8		20.1
845 + 13.0		
824 + 14.5	(5) 26.2	29.4
5026 + 81.3	(5) 26.5	
÷ 1		
5107	(3) 26.1	56.4

Log 5107 =

Mean of G(3.w) = 26.33

Mean of 5(c) = 26.06

Note.
Manometer has gotten air into it. The correction that must be applied on this account at pressure of 73.63 (on manom.) is + 1.18 cm.

12/4/11

$t = 24.4$
$p = 76.73$

dist = 10.06

Volts		G	F
829 +	14.2	22.2	
832 +	13.9	21.8	
795 +	15.8	22.1	
845 +	13.0	22.2	17.2
827 +	14.3	22.0	46.9
818 +	15.0	22.0	151.6
4946	86.2	22.0	70.6
86.2			71.6
5032.2			71.8
			71.4
			71.4
			152.8

slight ... (beside the first G readings)

22.043

changing ... (beside the column below)

21.898
22.076
21.446
21.460
22.018
22.036
22.060
22.156

8)176.190
22.024

$v_1 = \frac{10.06}{22.024} = .04567$ — .0025, 1.3429, 2.6596

$v_2 = \frac{10.06}{152.2} = .006609$; 4567 = .05228 — .0025, 2.1820, 3.5201

$v_2' = \frac{10.06}{71.36} = .01410$; 4567 = .05977 — .0025, 1.8535, 3.1490

$v_2'' = \frac{10.06}{46.9} = .02144$; 4567 = .06711 — .0025, ..., 3.3313

$v_2''' = \frac{10.06}{19.67} = .05114$; 4567 = .09681 — .0025, 1.2939, 2.7086

$v_2'''' = \frac{10.06}{17.2} = .05847$; 4567 = .10414 — .0025, .2355, 2.7670

7).05228 = .007468; 8).05977 = .007471; 9).06711 = .007457; 13).09681 = .007447; .007434

Mean $v_1 + v_2$ = .007462

Log $v_1 + v_2$ = -3.8728
$\frac{3}{2}$ " v_1 = -1.3298
3.1983
-4.4009
3.7018
10.6991

5.001
32
5.033 which is 3.2 % low

12/9/11

Tem 24.25 $p = 75.23$ $d = 1022$

G	F		
~~2.650~~			
5.300	9.116 c		
5.208	9.096 c		
5.266			
5.274	9.270 c	9.4	
5.268	9.408 c		
5.190			
5.268	9.516 c		
5.194			
5.116			
5.198			
5.238	30.6 s	30.6	
5.224	~~39.69~~ c	39.5	
5.350	39.2 sw		
5.260			
5.186			
5.362	~~44.6~~ sw		
	45.1 sw	45.3	
	45.8 sw		
	45.6 sw		

.0094 / .1834 / .1927 $v_1 = \frac{1.022}{5.192} = .19663$

.0094 / .1661 / .3533 $v_2 = \frac{1.022}{45.5} = .02246$; .19663; .21909 ÷ 60 = .0036518

.0094 / .3964 / .4124(?) $v_2' = \frac{1.022}{39.2} = .02607$; .19663; .22270 ÷ 61 = .0036509

.0094 / .4953 / .5837 $v_2'' = \frac{1.022}{30.6} = .03340$; .19663; .23003 ÷ 63 = .0036514

.0094 / .9625 / .0479 $v_2''' = \frac{1.022}{9.28} = .1101$; .1966; .3067 ÷ 83 = .003695

mean $v_1 + v_2$ = .0036514

Log $v_1 + v_2$ = −3.5624
$\frac{1}{2}$ " v_1 = −1.6469
3.1483
−6.4076
3.7020
10.7020
5.035

5.270
~~5.2461~~
19 | 89160
5.245
mean 19
= 5.192

879 + 14.2
831 + 14.4
803 15.9
842 + 13.1
827 + 14.3
816 + 15.1
4998 . 86.6
866
50346

Unfortunately this cannot be counted since number is uncertain but must get some of these rapid speeds and chronograph and 10000 volts.

Sat. Dec. 16, 1911.

$t = 17.5°C.$
$p = 75.14$

dist. = 1.022 cm.

Volts	Stop Watch G	Stop Watch F	Chronoscope G	Chronoscope F
844 + 13.0	25.2	32.8	212.86	
847 + 13.0	25.2	26.3	87.45	
823 + 14.6	25.4	26.4	125.41	
850 + 12.9	25.6	33.2		
840 + 13.2		32.9		
673 + 16.8				
4977 + 82.7				
83				
4960				

log 4961 = 3.

Volts	S.W. G	S.W. F
4945	107.4	41.3
	107.3	41.2

log 4945 = 3.

Sat., Dec. 16, 1911

dist = 1.022 cm.

$t = 17.5$
$p = 75.4$

Sat., Dec. 16, 1911. | dist. = 1.022 cm. | t = 17.5 °C, p = 76.18 cm.

Volts	Stop watch G	Stop watch F
838 + 13.3	29.9	
839 + 13.3	30.0	
822 + 14.6	30.0	
546 + 13.0	29.9	
834 + 13.7	29.6	
670 + 17.2	29.8	38.4
4949 + 85.0	30.2	
85		28.9
4934	29.9	
		56.9
	29.9	29.0
	29.6	38.6
	29.4	38.9
G. s.w. mean	29.8	38.8
		23.2
		57.8

Chronoscope G

159.61 − 10.67 = 148.94 ; 29.788	268.23 − 59.61 = 148.62 ; 29.724	172.52 − 23.34 = 149.18 ; 29.836	
171.61 − 22.52 = 149.09 ; 29.818	213.66 − 64.65 = 149.01 ; 29.802	162.89 − 13.66 = 149.23 ; 29.846	211.38 − 62.89 = 148.49 ; 29.698
159.63 − 11.38 = 148.25 ; 29.650			

Chronoscope F

66.56 − 8.23 = 58.33 ; 11.666	222.52 − 79.88 = 142.64 ; 28.525	264.69 − 71.61 = 193.04 ; 38.608

29.788
29.724
29.836
29.818
29.802
29.846
29.698
9) 208.512
29.650
G. c. mean
9) 238.162
29.770

Mean

	s.w.	c
G.	29.80	29.770
F.	38.675	38.608
F.′	28.95	28.52

.0094 / .4738 / −2.8356

$v_1 = \frac{1.022}{29.778} = .03433$

.0094 / .5846 / 2.4214

$v_2 = \frac{1.022}{38.64}$, .02650 + .03433 = .06088 ÷ 7 = .008690

.0094 / .7386 / 2.2508

$v_2' = \frac{1.022}{57.35}$, .01782 + .03433 = .05215 ÷ 6 = .008691

.0094 / .5386 / 2.5509

$v_2'' = \frac{1.022}{28.74}$, .03556 + .03433 = .06989 ÷ 8 = .008736

~~$v_2''' = \frac{1.022}{}$~~

.0094 / .3655 / .6439

$v_2''' = \frac{1.022}{23.2}$, .04404 + .03433 = .07837 ÷ 4 = .008708

.0094 / .0672 / 1.9422

$v_2'''' = \frac{1.022}{11.666}$, .08758 + .03433 = .12191 ÷ = .008708

mean $v_1 + v_2$ = .008691

Log $v_1 + v_2$ = −3.9341
Log v_1 = −1.2678
3.1983
6.4052
3.6932
10.7120

5152
128
5.024

This is 4% low.

Mon. - Dec. 18, 1911. | d = . | t = 18.1 °C. p = 76.36 cm.

Volts	G	F
847 + 13.6	(s) 37.6	(s) 10.5
846 + 13.0	(s) 37.9	
828 + 13.9	(s) 37.8	(s) 10.0
849 + 12.9	(s) 37.9	(s) 24.2
840 + 13.2	(c) 37.69	(c) 14.48 ?
709 + 16.8	(s) 38.0	(s) 24.0
	(c) 38.33	(s) 24.4
	(s) 38.2	(c) 24.51
	(s) 38.2	(s) 46.4
	(s) 38.2	

Mon. Dec. 18, 1911 } d = } t = 18.0° C.
p = 76.83

G	F
(s) 32.0	(s) 14.9
(c) 32.6	(s) 16.2
(c) 32.2	(c) 19.8
(c) 32.1	(s) 24.9
(s) 32.2	(s) 27.8
(c) 32.6	

Volts
droppings

Tues. Dec. 19, 1911. } d = } t = 21.0 C.
Pos. and reddial F p = 76.13 cm.

G

(s) 26.9
(c) 27.34
(s) 27.3
(c) 27.39
(s) 27.4
(c) 27.37
(s) 27.3
(c) 27.35
(s) 27.5

Commenced observ. at 2:00 P.M.
Ended obs. at 2:20

(c) 8.07
(s) 20.7
(s) 31.2
(c) 43.17

Volts at 2:00 P.M.

856 + 12.5
855 + 12.5
842 + 12.2
860 + 12.8
852 + 12.9
858 + 12.8
5126 + 11.3
77
5203

Volts at 2:20 P.M.

846 + 13.0
848 + 13.0
834 + 13.7
857 + 12.8
849 + 12.9
855 + 12.8
5089 + 78.2
78
5167

Tuesday, Dec. 19, 1911. | d =

$t = 21.0°C.$
$p = 76.34$

Readings from 2:40 to 3:00

Volts at 4:05 P.M.	G	F
8447 13.0	(s) 31.8	
845 + 13.0	(s) 31.8	(s) 19.9
829 + 14.2	(c) 31.56	(s) 14.8
552 + 12.9	(s) 31.6	
843 + 13.1	(c) 31.70 (2 of 3)	(s) 24.4
849 + 13.0	(c) 31.62	(s) 14.6
5062 + 79.2	(s) 31.6	(s) 31.6
79	(c) 31.53	(s) 14.4
5141	(s) 31.8	(c) 31.54
	(c) 31.76	(s) 73.7
	(s) 31.7	(s) 14.2

Tues., Dec 19, 1911 { d = — = 8 divisions } $t = 21.6°$ C.

Readings from 3:15 to 3:50 P.M. $p = 76.46$

G F

1st (5) 63.6 = 1 division time
2nd (5) 78.2 = 1 division
3rd (5) 56.6 = 1 division
4th (5) 68.6 = " "
5th (5) 44.0 = " "
6th (5) 60.0 = " "
7th (5) 66.0 = " "
8th (5) 66.8 = " "
(5) 63.0 = " " " 31.8 = 8 divisions.
1st (5) 45.2 = " " "
(5) 46.0 = " " "
(5) 50.8 = " " "
(5) 55.0 = " " "
(5) 58.2 = " " "
6th (5) 58.0 = " " "

31.8 = 8 divisions

1st (5) 38.8 = " " "
2nd (5) 45.0 = " " "
3rd (5) 49.0 = " " "
4th (5) 54.0 = " " "

This work in observing slow drops was done to see whether there were appreciable convection currents. The results indicate that there are. Must look more carefully hence for the problem of room.

Tues. Dec. 19, 1911

d =

t = 22.5 °C.
p = 77.38 cm.

5:35 to 6:12 P.M.

Volts at 6:15

841 + 13.2
841 + 13.2
817 + 15.0
846 + 13.0
834 + 13.7
840 + 13.2
5019 + 81.3
81
5100

G

(s) 27.4
(s) 27.6
(c) 27.74
(s) 27.6
(s) 27.9
(c) 27.72
(c) 27.85
(c) 27.60
(c) 27.76
(c) { 27.76
14.2 = (s) time 1st ½ dist.

27.76
27.76
27.67
27.85
27.74
27.74
6)4.43
74
Mean = 27.74

(s) 72.1
(s) 72.2
(s) 45.7
(s) { 25.7
13.2 = time 1st ½ dist.
s { 33.4
17.0 = time 1st ½ dist.

F

.0044
1.4482
2.5663

$v_1 = \frac{1022}{27.74} = .03684$

.0044
8582
1576

$v_2' = \frac{1022}{72.15} = .01416$
3684
− .05100 = 6 .00850

.0044
4627
−3.5941

$v_2'' = \frac{1022}{25.7} = .03977$
3684
− .07661 ÷ 9 = .00851

.0044
5238
4867

$v_2''' = \frac{1022}{33.4} = .03060$
3684
− .06744 ÷ 8 = .008430

$\frac{1022}{45.7} = .02236$
3684
− .05920 ÷ 7 = .008457

Mean $v_1 + v_2$ = .008480

Log $v_1 + v_2$ = 3.9284
$\frac{1}{2}$ " v_1 = −1.2831
3.1983
−1.4098
3.7076
10.7022

5034
11
5037

about 3% too low.

Wedn., Dec. 20, 1911. } d = } t = 22.0°C.
p = 76.9

obs. from 3:30 to 3:45 P.M.

Volts at 3:15 P.M.

852 + 12.9
853 + 12.9
839 + 13.2
859 + 12.8
545 + 12.9
857 + 12.8
5108 + 77.5
76
5184

G

(5) {29.8 / 14.0 = 1st half distance

(5) {29.8 / 14.9

(5) {29.8 / 14.9 = 1st ½ dist

(6) {30.1 / 15.2 = 1st ½ dist.

(5) {29.6 / 14.6 = 1st ½ dist.

(5) 29.64

(5) 29.89

(5) {30.2 / 15.2 1st ½ dist.

F

(5) 7.4

(5) 11.3

(5) {102.8 / 50.2 = 1st ½ dist.

Volts at 3:50 P.M.

849.5 + 12.9
851.5 + 12.9
826 + 14.5
855 + 12.8
844 + 13.0
854 + 12.8
5080.0 + 78.9
79
5159

s = 29866
c = 29865

.00494
.4151
2.6243

$v_1 = \frac{1022}{29.86} = .03422$

$v_2 = \frac{1022}{101.6} = .01006$

$v_1 + v_2 = .04428 \div 5 = .008856$

log $v_1 + v_2$ = 3.9472
½ " v_1 = 1.2672
3.1983
6.4127
3.7126
10.7000

5013
22
4991

Conditions of this run particularly good & results should be more than usually reliable. We kept temp very constant with fan & precaution not heretofore taken in room 12 but found yesterday to be quite essential

Wednes., Dec. 20, 1911. | d =   t = 22.2°
p = 78.03 cm.

pos. dirf.
Volts at   obs. taken from 4:00 to 4:30 P.M.

4:30 P.M.

Volts	G	F
847 + 13.0	(s) 14.0	(s) 29.2 out of field
849 + 12.9	(s) 14.0 7.0 = 1/2	(s) 28.9 14.4 = 1st 1/2 dist
820 + 14.8	(c) 14.11	(s) 25.7 14.6 = 1st 1/2 dist
852 + 12.9	(c) 14.28	(s) 24.2
841 + 13.2		(s) 24.6
851 + 12.9	(c) 14.11	(s) 24.7
5060 + 79.7		(s) 24.6
80.1	(c) 14.13	(s) 43.6
5140	(c) 14.02	(s) 44.4
	(c) 14.00	(s) 45.1
	(c) 14.10	(s) 45.6
	(c) 13.95	(s) 102.6
	(c) 13.89	(s) 104.0
	11) 154.59	(s) 104.0
	14.05	(s) 105.8 52.4 = 1st 1/2 dist.

24.5

4) 178.7 44.68

1048

.0044 1436 = .2818 $v_1 = \frac{1022}{14.05} = .07274$

.0044 9.24 = .4930 $v_2 = \frac{1022}{104.8} = .00977 + .08256 ÷ 13 / 7274 = .006351$

.0044 .6503 = .3593 $v_2' = \frac{1022}{44.68} = .02288 + .09562 ÷ 15 / 7274 = .006375$

.0044 .3892 = .6222 $v_2'' = \frac{1022}{24.5} = .04171 + .11445 ÷ 18 / 7274 = .006358$

.0044 .4603 = .5485 $v_2''' = \frac{1022}{24.9} = .03536 + .10810 ÷ 17 / 7274 = .006359$

.006351
.006375
.006358
.006359
4) .025443
.006361 = mean v_1 etc.

Log v_1 etc. = −3.8036
3/2 v_1 = −1.4309
3.1442
6.4328
3.7110
10.7218

5.270
19
5.251

This is a good drop and is 3/4 high

[illegible]

Crossed-out column: 14.0, 14.0, 13.84, 14.45, 14.00, 14.02, 14.13, 14.1, 14.18, [illegible], 6) 13.53, 14.09 [illegible]

Wednes., Dec. 20, 1911 { d =

$t = 22.3°C.$
$p = 78.23$ Cm.

obs. from 4:45 to 5:30 P.M.

Volts at 5:30 P.M.

841 + 13.2
844 + 13.0
817 + 15.0
851 + 12.9
840 + 13.2
850 + 12.9
5043   80.2
80.2
5123.2

G

(S) {93.0
{42.3 = 1st half

(S) {96.7
{48.7 = 1st ½ dist.

(S) {96.2
{49.0 = 1st ½ dist.

(S) {96.2
{48.7 = 1st ½ dist.

(S) {95.5
{49.0 = 1st ½ dist.

(S) {93.0
{44.0 = 1st ½ dist.

right in middle portion of field. (S) {92.0
{46.0 = 1st ½ dist.

F

(S) 29.7

(S) {51.5
{26.0 = 1st ½ dist.

(S) {97.4
{49.0 = 1st (A) dist.

(S) {28.7
{14.6 = 1st ½ dist.

(S) {51.0
{26.0 = 1st ½ dist.

(S) 227.5

(S) {29.0
{14.8 = 1st ½ dist.

In middle portion of field.

(S) {232
{106.0 = 1st ½ dist.} in upper portion of field

97 490
93.0 443
96.7 487
96.2 490
96.2 487
95.5 490
93.0 440
92.0 460
~~7606~~ 8683
94.46 47.79

.0044
-3.9786
-2.3379

$v_1 = \frac{1022}{94.46} = .01081$

$v_2 = \frac{1022}{51.60} = .019806 - .010795$; .030581 ÷ 2 = .01529

$v_2' = \frac{1022}{227.5} = .004492 + .010790$; .015282 ÷ 1 = .01528

$v_1'' = \frac{1022}{97.4} = .01049 + .010790$ ~~.....~~

$v_3''' = \frac{1022}{29.13} = .03508 + .010790$; .04585 ÷ 3 = .01528

Mean $v_1 + v_2$ = .015278

Log v_{1+v_2} = -2.1839
L. v_1 = -2.0159
3.0983
-6.3981
3.7092
-13.6482

$e = 4.98$ which means that this could not have been an oil drop.

Wednes., Dec. 20, 1911

pos. drop.

$t = 22.2°C$

$p = 79.18$

Obs. from 5:45 to 6:15 P.M.

Volts at 6:20

845 + 13.0
846 + 13.0
814 + 15.3
853 + 12.9
839 + 13.2
847 + 13.0

5041. 80.4
80.4
5121.4

c	s
10.30	10.30
10.28	10.30
10.29	10.30
10.24	~~10.27~~
10.32	10.30
10.31	10.25
10.36	
10.28	
10.24	
10.26	
10.33	
10.24	
10.20	
~~10.288~~	
10.29	

G

(c) 10.30
(s) 10.20
(c) 10.28
(c) 10.27
(s) 10.30
(c) 10.24
(s) 10.20
(c) 10.32
(s) 10.3
(c) 10.31
(c) 10.36

(c) 10.28

~~(c) 10.23~~

(c) 10.28
(c) 10.26
(c) 10.33
(c) 10.24
(c) 10.26

F

.0044 / 1.3536 / 3.3990

$v_1 = \frac{1022}{10.29} = .09932$ / .09951

.0044 / 5968 / 0826

$v_2 = \frac{1022}{948} = .01078$ / .09932 — .11010 ÷ 21 = .005243

.0044 / 8003 / 7857

$v_2' = \frac{1022}{63.2} = .01617$ / .09932 — .11549 ÷ 22 = .005249

.0044 / 6785 / 3709

$v_2'' = \frac{1022}{47.76} = .02140$ / .09932 — .12070 ÷ 23 = .005250

.0044 / 2143 / .7981

$v_2''' = \frac{1022}{381} = .02683$ / .09932 — .12615 ÷ 24 = .005256

$v_2'''' = \frac{1022}{16.23}$ .06248 / .09932 — .16180 ÷ 31 = .005235

Diff.

.11549	.12070	.12634	.16249
.11022	.11549	.12075	.12634
.00527	.00521	.00529	7/.03615
			.00516

mean diff = .005304

mean $v_1 + v_2$ = .005245

Log $v_1 + v_2$ = 3-3.7204
½ " v_1 = -1.4986
-3.1983
-6.4169
3.7294
7075

5099 / 14 / 5096

5099
15
5.081

(s) 16.3
(s) 16.2
(s) 16.2

(s) {37.8 / 18.9 = 1st ½ div.

(s) 38

(s) {38.0 / 19.0 = 1st ½ div.

(s) {38.6 / 19.2 = 1st ½ div.

(s) {47.6 / 23.0 = 1st ½ div.

(s) {62.2 / 30.8 = 1st ½ div.

(s) {63.3 / 31.7 = 1st ½ div.

(s) {63.3 / 31.9 = 1st ½ div.

(s) 64.3

(s) {94.0 / 47.0 = 1st ½ div.

{95.6 / 47.4 = 1st ½ div.

This is almost exactly right & the best one I ever had !!!

Never had better conditions than with this drop. It was without bubbles and no indication of convection

An exactly balanced speed.

Thursday Jan. 4, 1917.

Volts

1 –	857 + 12.8	=	869.8
2 –	862 + 12.8	=	874.8
3 –	~~723~~ 663 + 15.6	=	678.6
4 –	862 + 12.8	=	874.8
5 –	853 + 12.8	=	865.8
6 –	860 + 12.8	=	872.8
	4957 + 79.6		5036.6
	79.6		
	5036.6		

t = 17.2 p = 7401 (1)

b

21.60 (S)
21.53 (C)
21.80 (S)
21.51 C
21.80 S
21.68

13.86 (C)
14.15 (C)

21.71 (C)

46.2 (S)

46. (S)

21.77 (C)

45.8 (S)

21.57 (C)

46.0 (S)

21.63

t = 17.2 p = 7401

volts

1.	853 + 12.8	=	865.8
2.	847 + 13.	=	860.0
3.	825 + 14.5	=	839.5
4.	855 + 12.8	=	867.8
5.	842 + 13.1	=	855.1
6.	854 + 12.8	=	866.8
	5076 + 79.0	=	5155.0
	79		
	5155		

.0094
3351
6743

$v_1 = \frac{1021}{21.63}$ .04724

$v_2 = \frac{1021}{46.0}$ = .02222
.04724
.06946

$\log v_2 + v_2$ = -2.8418
$\frac{1}{2} \log v_1$ = -1.3377
-3.1983
5.3778
3.7162
9.6451

4625
122
9) 45.03
e_1 = 5.003

3" = 9.0 lbs

$t = 17.4$ $P =$

Volts

1 - 849 + 12.9 = 861.9
2 - 844 + 13.0 = 857.0
3 - 820 + 14.8 = 834.8
4 - 850 + 12.9 = 862.9
5 - 834 + 13.6 = 847.6
6 - 851 + 12.9 = 863.9

Volts 5048 + 80.1 = 5128.1
801
5128.1

5.		7.	
17.2	(S)		
17.07	(C)		
17.3	(S)	14.99	(C)
17.51	(C)	42.7	(S)
17.48	(C)	42.4	(S)
17.46	(C)		
		32.7	(S)
		33.0	(S)
17.49	(C)		
		32.8	(S)
17.46	(C)		
		42.4	(S)
17.50	(C)		
		42.0	(S)
17.47	(C)		
		42.6	(S)
17.39	(C)		
		101.0	(S)
8) 139 76			
17.47			

.0044 / 1.3922 / 2.7870

$V_1 = \frac{1022}{17.47} = .05850$

$V_2 = \frac{1022}{101.0} = .01011$ $.05850$ $= .06861 \div 10 = 006861$

.0044 / 6.484 / 3.8825

$V_2' = \frac{1022}{42.82} = .02410$ $.05850$ $= .08260 \div 12 = 006883$

$V_3' = \frac{1022}{32.83}$ $.03113$ $.05851$ $= .08964 \div 13 = 006895$

$V_1 + V_2 = .006880$

$\log V_1 + V_2 = \bar{3}.8376$
$\log V_1 = \bar{1}.3836$
$\bar{3}.1483$
6.4195
7100
$.2095$

5.12ν
1245
4.9935

$e_1 =$

which is 3% low

Thursday Jan. 11th 1912. **New Menometer**

t = 19.1 t = 19.2

Volts

1 – 858	+ 12.8 = 870.8	@ 12.05
2 – 859	+ 12.8 = 871.8	
3 – 842	+ 13.1 = 855.1	
4 – 863	+ 13.0 = 876.0	
5 – 851	+ 12.9 = 863.9	
6 – 857	+ 12.8 = 869.8	
5130	+ 77.4 = 5207.4	
724		
5207.4		

@ 2:15

1 – 851 + 12.9 =	863.9
2 – 852 + 12.9 =	864.9
3 – 838 + 13.4 =	851.4
4 – 853 + 12.8 =	865.8
5 – 849 + 12.9 =	861.9
6 – 847 + 12.9 =	859.9
5090 ·	+77.8 = 5167.8
778	
5167.8	

B F

Obs. taken at 3:25 P.M. t = 19.4 P = 76.61 (no correction - new menometer)

watch at 4:00 P.M.

65.3	12.8
32.2 } ½	21.6
65. }	
32.7 } ½	
65. }	
32.2 } ½	31.8
64.9 }	
31.7 } ½	31.7
64.7 }	
32.6 } ½	
64.8 }	
	32.0 } ½
	64.8 }
64.9	
	16.4 } ½
63.8	
31.3 } ½	16.0 } ½
63.2 }	32.2 }
62.8	32.6
31.6	21.2
63.1	

Obs. finished at 3:55

2nd obs. starts @ H: 10 t = 19.4 P. 76.90

Volts at H: 00

1 = 846 + 13.0 = 859
2 = 846 + 13.0 = 859
3 = 819 + 14.9 = 833.9
4 = 852 + 12.9 = 864.9
5 = 834 + 13.5 = 847.5
6 = 843 + 13.1 = 856.1

5140 + F 80.4 = 5120.4

16.6-S
16.38-C
16.4-S
16.3-S
16.49-C
16.39-C
16.49-C
16.6-S
16.41-C
16.5-C
16.60-C
16.50-C
16.45-C

14.00-S
15.80-S
31.20-S
25.20-S

3rd Obs. starts at 4.38 t = 19.5 P = 77.16

Volts at 4:30

1 - 844 + 13.0 = 857.0
2 - 845 + 13.0 = 858.0
3 - 816 + 15.1 = 831.1
4 - 851 + 12.9 = 863.9
5 - 833 + 13.8 = 846.8
6 - 843 + 13.1 = 856.1

5034 + 80.9 = 5112.9
80.9
5112.9

Volts at 4'56

1 - 843 + 13.1 = 856.1
2 - 843 + 13.1 = 856.1
3 - 815 + 15.2 = 830.2
4 - 850 + 12.9 = 862.9
5 - 834 + 13.6 = 847.6
6 - 841 + 13.2 = 854.2

5046 + 81.1 = 5107.1
81.1
5107.1

G		F	
26.6	-5	84.8	5
		24.2	5
26.45	- e	45.8	5
26.35	- C	45.9	5
26.31	- e	41.9	5
26.30	- e	8443	

Finished at 4.53

4th Obs. starts at 5:10 $t = 19.5$ $P = 78.05$

Volts taken @ 4.55 see last page

B.		F
~~15.37~~		
~~15.81~~		
13.65	c	
13.71	c	
13.83	c	
13.76	c	
13.70	s	
13.71	c	
13.70	c	
13.82	c	22.9 - s
		22.6 - s
		26.2 - s
		26.3 - s
13.75	c	26.0 - s
13.76	c	68.0 - s
13.71	c	49.1 - s
13.77	c	
12)164.87		
13.74		

Finished @ 5.45

Volts taken again - see next page.

.0014
1.1360
2.8714

$v_1 = \frac{1022}{13.74} = .07438$

$v_2 = \frac{1022}{68.0} = \frac{.01503}{.07438} = .08941 \div 15 = .005960$

$v_2' = \frac{1022}{49.1} = \frac{.02082}{.07438} = .09520 \div 16 = .005950$

$v_2'' = \frac{1022}{26.17} = \frac{.03905}{.07438} = .11343 \div 19 = .005970$

$v_2''' = \frac{1022}{22.75} = \frac{.04492}{.07438} = .11930 \div 20 = .005960$

$v_1 + v_2$

mean volts = 50.98

$v_1 + v_2 = .005960$

$\log v_1 + v_2 = -3.7752$
$\log v_1 = -1.4357$
-3.1993 — const
$\overline{6.4092}$
3.7074 — log volts
$\overline{7085}$

5032
75
$\overline{4.957}$

which is nearly 49.90

.0045 for degree

23
32
12
7

5th Obs. @ 6:05 $t = 19.6$ $P = 78.4$

Volts at 5:45

1 - 842 + 13.1 = 855.1
2 - 839 + 13.2 = 852.2
3 - 810 + 15.6 = 825.6
4 - 850 + 12.9 = 862.9
5 - 833 + 13.9 = 846.9
6 - 839 + 13.2 = 852.2

5013 + 81.9 = 5094.9
81.9
5094.9

Volts at 6:35

1 - 836 + 13.6 = 849.6
2 - 831 + 14.0 = 845.0
3 - 808 + 15.7 = 823.7
4 - 845 + 13.0 = 858.0
5 - 832 + 13.9 = 845.9
6 - 839 + 13.2 = 852.2

4991 + 83.4 = 5074.4
83.4
5074.4

95.9
17.5
78.4

b_1	F
74.7 } = ½	27.8
152.4 } 77.7	
73.0 } = ½	33.6 } = ½
149.8 } 76.8	67.4 } 33.8
73.4 } = ½	34.6 } = ½
149.3 } 75.9	68.6 } 34
75.3 } = ½	14.0 } = ½
151.6 } 76.3	27.8 } 13.8
74.0 } = ½	14.3 } = ½
151.0 } 75.5	27.8 } 13.5
73.6 } = ½	33.6 } = ½
149.8 } 76.2	68.1 } 34.5
74.3 } = ½	
149.8 } 75.5	

74=F
230
152.4
149.8
149.3
150.3
151.0
149.8
149.6
10537
150.5

.0080
.1975
3.2319

$V_1 = \frac{1022}{150.5} = .06626$

$V_2 = \frac{1022}{68.03} \cdot \frac{.01523}{.006636} = .02187$

$V_2' = \frac{1022}{27.8} \cdot \frac{.03676}{.006636} = .04240$

$V_1 + V_2 = .02178$

$\log V_1 + V_2 = -2.33581$
$\frac{1}{2} \log V_1 = -2.91710$
3.1983
6.4474
3.70514
10.74 3.20
$e = 5.521$
84
5.437

which is 4.5% low

Friday, Jan. 12th 1912

Volts taken at 4:15 P.M. $t = 20.5$ $p = 76.3$

1 – 850 + 12.9 = 862.9
2 – 855 + 12.8 = 867.8
3 – 838 + 13.4 = 851.4
4 – 858 + 12.8 = 870.8
5 – 852 + 12.9 = 864.9
6 – 854 + 12.8 = 866.8

5107 + 77.6 = 5184.6
77.6
5184.6

B	F
25.4 —	
25.2 —	
25.196	
25.2 —	
25.166	39.6
	29.7
25.022	23.8 } 23.9
25.264	24.0 }
25.0 —	

Finish @ 4:35

25.196
25.166
25.022
25.264
100.648
25.162

$v_1 = \frac{1022}{25.162} = .040015$ .00945 / 1.40734 / -5.60211

$v_2' = \frac{1022}{39.6} = .025808$ .00945 / 1.59770 / -2.41175

$v_2'' = \frac{1022}{29.7} = .03441$ .00945 / .47276 / -2.53659

$v_2''' = \frac{1022}{23.9} = .04276$ .00945 / .37840 / -2.63106

$v_1'' + v_2' = .040015 + .025808 = .065823$ ÷ 8 = .008228

$v_1 + v_2'' =$ .040015 / .03441 / .074425 ÷ 9 = .008269

$v_1 + v_2''' =$ .040015 / .04276 / .082765 ÷ 10 = .008276

$v_1 + v_2 = .008258$

$\log v_1 + v_2 = 3.91657$

$\frac{1}{2} \log \frac{?}{?} v_1 = -1.30105$
-3.19330
-6.41622
3.71488
.70284

mean with .51727

5029
55
$e =$ 4974

1% low

2nd Obs.

95.0
18.2
76.8

Volts taken at 4:40 $t = 20.5$ $p = 76.8$

1 - 848 + 12.9 = 860.9
2 - 852 + 12.9 = 864.9
3 - 836 + 13.5 = 849.5
4 - 856 + 12.8 = 868.8
5 - 850 + 12.9 = 862.9
6 - 851 + 12.9 = 863.9
5093 77.9 5170.9
77.9
5170.9

$v_2^{ii} = \frac{1022}{63.0} = .01621$ .14228 .15849 ÷ 36 = .004402 →
.00945 .79069 .80076

$v_2^{v} = \frac{1022}{85.6} = .01166$ .14228 .15394 ÷ 35 = .004398 →
.00945 .93247 .06698

$v_2^{vii} = \frac{1022}{109} = .009376$ .14228 .151656 ÷ 34 = .004460
.00945 .08743 .97702

Obs. taken at 4:50

G_1	7	
7.238		
7.306		
7.158		
7.130		
7.174		
7.056		
7.124		
7.448 -		
7.174		
7.062 -	19.402	
	10.286	
7.192	10.288	10.305
	10.392	
7.218		
	11.830	
	14.008	
7.094		

v_2^{ii} 1022/63.05 .00945 .79860 .80976 .01621 .14228 .15849 ÷ 36 = .004402

$v_1 = \frac{1022}{7.188} = .14228$ .00945 .84860 .15284 $\sqrt{1.15284 - 2}$ .67642 - 1

$v_2' = \frac{1022}{10.305} = .099175$ .00945 1.01385 -2.99640

$v_2'' = \frac{1022}{11.830} = .086392$ .00945 1.93649 -2.83647

$v_2''' = \frac{1022}{14.008} = .072958$ .00945 1.14636 -2.86307

$v_2^{v} = \frac{1022}{19.402} = .05268$ .00945 1.27380 -2.72163

$v_1 + v_2' = .14228 + .099175 = .241455$ ÷ ~~36 = .006707~~ ÷ 55 = .004395

5170.9
5148.9
119.8
5159.9

$v_1 + v_2'' = .14228 + .086392 = .228672$ ÷ ~~34 = .006726~~ ÷ 52 = .004397

$v_1 + v_2''' = .14228 + .072958 = .215238$ ÷ ~~32 = .006726~~ ÷ 49 = .004392

$v_1 + v_2^{v} = .14228 + .05268 = .19496$ ÷ ~~29 = .006723~~ .006720 ÷ 44 = .004430

down with G_1
60 small div.

124.0 = ½ dist.
259.8 = whole dist. (34) (33) .004300 .4431

136.6 = ½ dist.
282.9 = whole (33) .004421

62.8
63.3
85.6
54.0 = ½ of 1 div.
109.0 = ½ half of dist.

log $v_1 + v_2$ = ~~.38240~~ - 64365
57642

½ log v_1 = -1.57642 57642
-3.14830 1.4830
-6.60213 1.41837
.71263
log 51599 = 3.71264 .70573
.88948

.004395
4397
4392
4430
4402
4398
24114
.004402

5078
51
E = 5027

~~4783~~
885
~~2669.6~~

7.228
.5 | 2816
7.188

finished at 5:29.

3rd Obs. t = 20, p = 76.35

Volts at 5:30 P.M.

1 - 846 + 13.0 = 859.0
2 - 851 + 12.9 = 863.9
3 - 828 + 14.3 = 842.3
4 - 853 + 12.8 = 865.8
5 - 845 + 13.0 = 858.0
6 - 847 + 12.9 = 859.9
5070 + 78.9 = 5148.9
789
5148.9

Volts taken at 6:05

1 - 846 + 13.0 = 859.0
2 - 850 + 12.9 = 862.9
3 - 827 + 14.4 = 841.4
4 - 853 + 12.9 = 865.9
5 - 844 + 13.0 = 857.0
6 - 847 + 12.9 = 859.9
5067 + 79.1 = 5146.1
79.1
5146.1

S.	F		
18.912			
18.932			
18.868			
19.052	19.5 (5)	19.33	
	19.2 (5)		
18.980			
18.964			
	17.0 (5)		
18.976	17.1 (5)	17.07	
19.108 (?)	17.1 (5)		
	19.3 (5)		
18.984	42.2 (5)	42.2	
18.912	42.2 (5)		
18.990	101.9 (1)		
9570			
18.957			
6.03 p.m.			

$V_1 = \frac{1022}{18.957} = .005391$ .00945 / 1.27777 / 4 - 2.73168 / -1.36584

$V_2' = \frac{1022}{17.07} = .05987$ .00945 / 1.23223 / -2.77742

$V_2'' = \frac{1022}{19.33} = .05287$ .00945 / 1.29623 / -2.72312

$V_2''' = \frac{1022}{42.2} = .02422$ .00945 / 1.62531 / -2.38414

$V_2^{IV} = \frac{1022}{101.9} = .01003$ .00945 / -.00817 / -2.00128

$V_2' + V_1 = .05391 + .05987 = .11378 \div 16 = .007111$

$V_2'' + V_1 = .05391 + .05287 = .10678 \div 15 = .007118$

$V_2''' + V_1 = .05391 + .02422 = .07813 \div 11 = .007103$

$V_2^{IV} + V_1 = .05391 + .01002 = .06394 \div 9 = .007104$ / .007109

85181. $V'+V''$ = .003009

$\log(V_1+V_2) =$ 47842
$\frac{1}{2}\log V_1 =$ 26584 / 19830 / 6.04256 / 3.77164 / .33092

46595 / 71164 / 10431

volts = 5148

5062 / 68

e = 4.994

Saturday. Jan. 21, 1911. Magnification 1005

Volts at 2:45 t = 23. P = 9563 - 1754 = 7709

1 - 869 + 12.9 = 881.9
2 - 872 + 13.0 = 885.0
3 - 860 + 12.8 = 872.8
4 - 876 + 12.1 = 889.1
5 - 855 + 12.8 = 867.8
6 - 870 + 12.9 = 882.9
5202 + 77.5 = 5279.5
77.5
5279.5

Volts at 3:50 P.M.

1 - 852 + 12.9 = 864.9
2 - 826 + 14.5 = 840.5
3 - 845 + 13.0 = 858.0
4 - 863 + 12.9 = 875.9
5 - 845 + 13.0 = 858.0
6 - 858 + 12.8 = 870.8
5089 + 79.1 = 5168.1
79.1
5168.1

17, 16, 15, 14, 10, 15, 120

5279.5
5168.1
111.4

Obs. began at 3:13 P.M.

G	F
	27.8
25.2	27.8
	19.2
25.558	
25.2	52.4
25.494	91.7
25.8	91.5
25.566	
	46.3 = ½
25.278	92.4
	46.6 = ½
25.260	93.4
	47.
25.564	94.
	93.4
25.382	
	47.2 = ½
	94.4
25.394	

8 | 3.496
25.462
3:48
25.462

$v_1 = \frac{1005}{25.462} = .03947$

$v_2' = \frac{1005}{19.2} = .05234$
.03947
.09181

$v_2'' = \frac{1005}{27.8} = .03615$
.03947
.07562

$v_2''' = \frac{1005}{52.4} = .01918$
.03947
.05865

$v_4'' = \frac{1005}{93.0} = .010686$
.03947
.050356

.002166
.405892
-3.596274
-1.298137

.002166
.162305
.7.71983 - 2

.002166
.449042
.88612 - 2

.002166
.719321
.28333 - 2

.002166
.9.02155
.033653 - 2

$v_1 + v_2' = .09181 \div 11 = .00836$

" = .07562 ÷ 9 = .00840

" = .05865 ÷ 7 = .00838

" = .050355 ÷ 6 = .00839
.00838

$\ell(v_1 + v_2) = .930123 - 3$
$\frac{3}{2} \log v_1 = .28137 - 2$
.11880 - 3
4.16550
.716043
.700547

log 5300

e = .5.0187