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 TWO:
March-April 1912

PART 1 OF 3
From page 1 to page 29

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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

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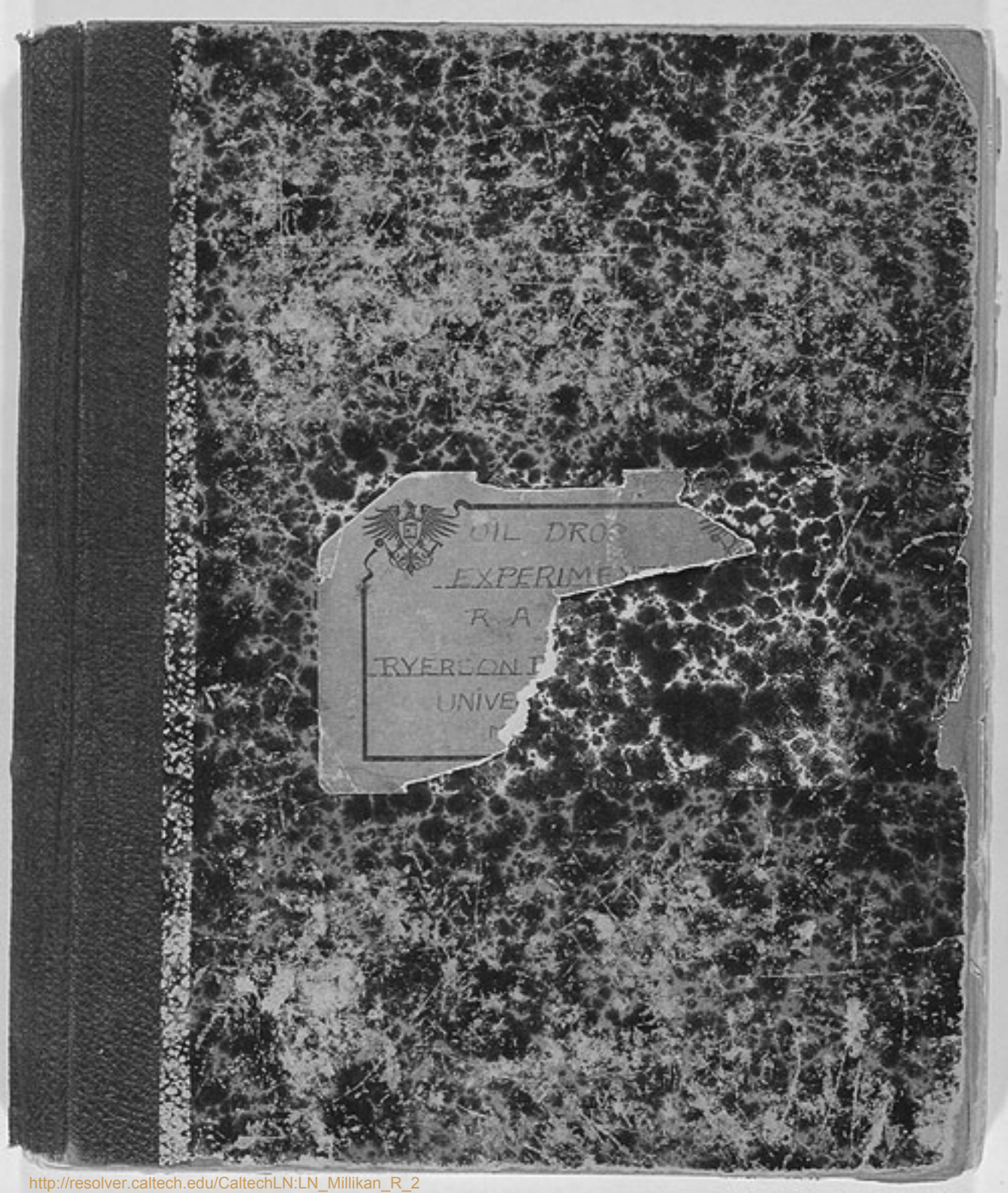

TABLE OF CORRECTIONS - TO VOLTMETER 2539
(R.I. No. 1508)

300 − 6.4	782 + 17.0		836 + 13.6	13.1	
325 − 5.8	784 + 16.9		7 + 13.5	13.0	
350 − 4.8	786 + 16.8		8 + 13.4	12.9	
375 − 4.0	788 + 16.7		9 + 13.3	12.8	
400 − 3.0	790 + 16.6	× 14.0	840 + 13.2	12.7	×
425 − 1.4	792 + 16.5	178	1 + 13.2	12.6	
450 + 0.2	794 + 16.4	176	2 + 13.1	12.5	
475 + 2.0	796 + 16.3	173	3 + 13.1	12.4	
500 + 3.6	798 + 16.2	17.0	4 + 13.0	12.3	
510 + 4.8	800 + 16.1	× 16.9	5 + 13.0	12.3	
520 + 5.0	1 + 16.1	16.8	6 + 13.0	12.2	
330 + 5.8	2 + 16.0	16.7	7 + 12.9	12.2	
540 + 6.5	3 + 16.0	16.6	8 + 12.9	12.1	
550 + 7.4	4 + 15.9	16.5	9 + 12.9	12.1	
560 + 8.6	5 + 15.8	16.4	850 + 12.9	12.0	×
570 + 9.9	6 + 15.7	16.3	1 + 12.9	12.0	
580 + 11.3	7 + 15.7	16.2	2 + 12.9		
590 + 12.7	8 + 15.6	16.1	3 + 12.9		
600 + 13.6	9 + 15.6	16.0	4 + 12.9		
610 + 14.2	810 + 15.5	× 16.0	5 + 12.8	12	×
620 + 14.6	1 + 15.5	15.8	6 + 12.8		
630 + 15.0	2 + 15.4	15.6	7 + 12.8		
640 + 15.2	3 + 15.4	15.5	8 + 12.8		
650 + 15.5	4 + 15.3	15.3	9 + 12.8		
660 + 15.7	5 + 15.2	15.2	860 + 12.8		
670 + 15.9	6 + 15.2	15.1	1 + 12.9		
680 + 16.2	7 + 15.1	15.0	2 + 12.9		
690 + 16.6	8 + 15.1	14.9	3 + 12.9		
700 + 16.9	9 + 14.9	14.8	4 + 12.9		
705 + 17.2	820 + 14.9	× 14.8	5 + 12.9		
710 + 17.4	1 + 14.8	14.7	6 + 12.9		
715 + 17.6	2 + 14.8	14.7	7 + 13.0		
720 + 17.8	3 + 14.7	14.6	8 + 13.0		
725 + 18.0	4 + 14.7	14.6	9 + 13.0		
730 + 18.1	5 + 14.6	14.5	870 + 13.0		
735 + 18.1	6 + 14.5	14.5	2 + 13.1		
740 + 18.1	7 + 14.4	14.4	4 + 13.1		
745 + 18.0	8 + 14.3	14.3	6 + 13.2		
750 + 18.0	9 + 14.2	14.3	8 + 13.3		
755 + 17.9	830 + 14.2	× 14.2	880 + 13.4		
760 + 17.8 × 19.6	1 + 14.1	14.0	2 + 13.5		
765 + 17.6	2 + 14.0	13.8	4 + 13.6		
770 + 17.5 × 19.3	3 + 13.9	13.6	6 + 13.7		
775 + 17.3	4 + 13.8	13.4	8 + 13.8		
780 + 17.1 × 18.7	835 + 13.6	13.2	890 + 13.8		

300.5

.06 4779
.04 4786
.3 4796
.15 4789
.08 4786
.02 4783
.4 4802
.52 4807
.18 4788

9 | 71[illegible]
4791

Sum 147 = 4.782

Wednesday March 13, 1912 θ= p=

Volt sat 4.20

G	F	
18.462	13.904	chronogisth-
18.092	(17.188)	struck bottom
18.288	19.618	
18.374		

68.0 + 15.9
~~84.5 + 14.1~~
84 4.0 + 12.0
84 8. + 12.9
~~65 1.0 + 18.5~~
59 1.0 + 24.2
84 4.0 + 13.0

657.0+
841.0+
830.5+
833+1 not used
839+
839+
819+
838+
838+

Wednesday, March 13, 1912.
2nd Obs.

$\theta = 22.94$

$p =$

Volts at 5:00 P.M.
(1) not used
(2) 838.0 + 13.4
(3) 839.0 + 13.3
(4) 819.0 + 14.9
(5) 837.5 + 13.4
(6) 838.0 + 13.4
4171.5 + 68.4
= 4239.9
4239

G	F
22.076	15.676
22.010	15.652
21.834	15.856
22.102	
21.948	110.4 —
21.886	

4:58 P.M.

Wednesday, March 13, 1912 $\theta = 22.91$ $p = \frac{6725}{5158} \; 75.67$
Third Obs.
5:15 P.M.

Volts at. 5:30   1st bank not used

837.0 + 13.0
838.0 + 12.9
819.0 + 14.4
837.0 + 12.9
837.0 + 13.0
4168.0 + 66.6 = 4234.8

(14) (37)

G	F	
	~~23.0~~	~~46.4~~
9.884	23.0	45.8
9.924	22.6	45.8
9.858		
9.860	—	37.6
	18.9	37.8
9.912	—	37.4
9.902		
9.902	—	58.6
9.904	—	81.6
9.902	41.6	82.6
9.814	16.0	31.9
	—	60.0
9.806	30.6	60.6
11) 9668		
9.879		

$\frac{1}{45.8} = .02183$

$\frac{1}{37.6} = .02660$

$\frac{1}{58.6} = .01706$

$\frac{1}{81.6} = .01225$ $\frac{1}{82.6} = .01211$

$\frac{1}{31.9} = .03135$

$\frac{1}{60.0} = .01667$

Differences

.02660 − .02183 = .00477
.02660 − .01706 = .00954, 477
1706 − 1225 = 481
3135 − 1211 = 4) 1924 = 481
3135 − 1667 = 3) 1468 = 489

1012 + 2183 = 2) 3195 ... 4731
1012 + 2660 = 2) 12760 ... 4733
1012 + 1706 = 2) 11626 ... 4731
1012 + 1218 = 2) 11338 ... 4722
1012 + 3135 = 4) 13235 ... 4716
1012 + 1667 = 3) 11767 ... 4715

4893, 481, 481, 477, 477, 5) 4851 = 4810

4731, 4733, 4731, 4722, 4716, 4715, 6) 1443 = 4725

mean of 4810 and 4725 = 4767 × 1021

5:30 P.M.

$\frac{1}{9.88} = .1012 \times 1.021 = v_1 = .10332$ $\times v_1 + v_2 = .004867$

$\log_q = -3.6872$
−1.50796
3.1983
−6.3925
13.62696
−10.76547
7656

$e_1 = 5.827$
5.825
$e_1 = 5820$

Log = −1.01412
" = −1.50701

Volts = 4236

a

−164270
362716
−1.01412
−1306628
−3.65782
3) −11.38406
−4.46035
1.19597
3.65692
2.34397

l

−4.8547
1.1951
−5.6596
−4.46063
−1.1980

.000 2695 = a

.1596 = l/a
.1582 = l/a
.1587
1589

2212 = $\frac{1}{pa}$

2219
2220

$e^{2/3}$

3) −10.7653
−4.4292
−7.8410
8434

7649
3) 5298
.28433
6928 = $e^{2/3}$
69.731

Publisher

3)

Thursday, March 14, 1912

First Observation

3:10 P.M.

Flickers some

$\theta = 23.00$

$p = \frac{67.40 - 51.85}{15.95}$ 16.05

Volts at 3:00 P.M.

836.0 (reduced)

840.5+12.7
840.5+12.6
822.0+14.1
840.0+12.6
841.0+12.6
4184.0+75.2 = 4261.6
4259.5

(15) 36

Brady

g		F		
9.314		11.954	11.927	
9.356		11.900		
9.294		17.820	17.759	.05631
9.216		17.726		
9.312		17.704		
9.254		17.786		
9.358		21.292	21.230	.04710
9.438		21.168		
9.366		19.624 ?		.5191
9.236		34.556	34.594	
	(17.6)	(34.7)		
9.270		34.632		
9.19.6	(17.6)	(34.0)	$\frac{1}{34.6}$ = .02890	
9.256		13.546	$\frac{1}{13.55}$ .07360	
9.232		23.592	$\frac{1}{23.59}$ .04239	
	—	(23.2)		
9.244		35.176	$\frac{1}{35.278}$ .02835	
9.206		35.370		
	(18.0)	(35.4)	$\frac{1}{35.4}$ .02825	
9.228	34.0	68.4	$\frac{1}{68.4}$ = .01462	
9.186				
18) 4.962				
9.265				

.01820 ÷ 4
= .004555

.04490 ÷ 10
= .004490

.03191 ÷ 7
= .004467

.01404 ÷ 3
= .04680

.01363 ÷ 3
= .004543

Differences
4543
4543
4680
4487
4490
4490
4550
7) 31783
.004540 mean dif.

.1080
1462
2) 1.2262
.004542

1080
2831
3) 13635
4545

1080
2890
3) 13690
4563

1080
4710
3) 15551
4562

1080
5631
3) 1.16431
4564

4542
4545
4563
4562
4564
5) 2276
4555

3:35 P.M.

.1050 × 1041 = 8

V_1 = .11027

.004555 × 1041 = V_1 ... .0046506

Log = −3.6676
−1.5213
3.1463
−6.3871
3.62807
−10.75963

5.7363 3) 10.75963
−4.41954
7.83987

$e^{2/3}$

e_1 = 5.735
e = 5.739 $e^{2/3}$ = 64.07

64.04

−4.8549
1.2041
3.6578 Volts = 4346
4.9764
−1.1738

.1462 = 1/4
11449

a
−16.4270
3.6283
−6.0425
−13.0980
−3.6626
3) −11.4304
−4.4768 .0002998 = a
2.4354

Log = −1.04245
$\frac{1}{2}\eta$ = −1.52138

Correct for thickness and other sets

1.2041
−3.8808

4) Second Observation Mar. 14, 1912 $t = 23.06$ $p = \frac{6773}{5098}$ 74.75

4:00 P.M.

Volts at 3:35 P.M.

(2) 837.5 + 13.5
(3) 838.5 + 13.4
(4) 820.0 + 14.9
(5) 838.0 + 13.4
(6) 838.5 + 13.4
4172.5 + 68.6 = 4241.1
4239

(16)
35

Beauty Publish

G		F	
12.136		8.332	
12.154		8.486	
12.038		20.620	$\frac{1}{20.59} = .04856$ } .00529
12.256		20.548	
12.054		23.116	$\frac{1}{23.11} = .04327$ } $\frac{.02111}{4} = .00528$
11.966		23.116	
		45.148 (45.4)	$\frac{1}{45.12} = .02216$
11.968	(22.4)	45.108 (45.2)	
12.012	(22.6)	45.320 (45.4)	$\frac{1}{45.4} = .02203$ } $\frac{.01064}{2} = .00532$
	44.2	88.0	
12.034		87.6	$\frac{1}{87.6} = .01139$
12.052	(41.0)	71.1	caught in route } .00495
11.994	30.6	61.4	
11.842	30.4	61.2	$\frac{1}{61.2} = .01634$
12.218	30.6	61.2	} .00541
11.968	46.0	91.6	$\frac{1}{91.6} = .01093$ } $\frac{.02077}{4} = .005192$
12.010	—	31.506	$\frac{1}{31.55} = .03170$
6)130.69		31.590 (31.6)	
12.040			

$\frac{1}{12.040} = .083206$; $1021 = v_1 = .08496$
$\log = -2.9292$
$\frac{1}{2}\log = -1.4646$

4:35 P.M.

Differences
529
528
532
495
541
5192
6)31442
.005240

From $v_1 + v_2$

.08321 / 3170 / 2).11491 / .005223

8321 / 1624 / (4)9954 / 5240

8321 / 1093 / (6)9414 / 5230

8321 / 1139 / (8)9460 / 5254

8321 / 2216 / 10)10537 / 5269

8321 / 4327 / 12648 / 5270

8321 / 4856 / 25)13177 / 5271

5223
5240
5230
5254
5269
5270
5271
7)362
5252

.005252 × 1021 =
$v_1 + v_2 = .005362$

$\log = -3.7294$
−1.4646
3.1963
−6.3923
3.6269
−10.7652

a
−16.4290
3.6271
−2.9292
−19.8252
−3.7284
3)11.2684
−4.4214 .002639 = a
1.2240
−3.6454
2.3546

b
−4.8547
1.2240
5.6307
−4.4214
−1.2093

.1614 = b/a
.1622

2263 = 1/pa
2275

5815
1
e_1 = 5.5246
5429
Error 3%

$e^{2/3}$
3)−10.7652
−4.9213
−7.8435
6876
e^3 6913

Publish this beautiful one Good

OK

Can't get wrong ...

Third Ole. Thursday Mar. 14, 1912 θ = 23.04 p = 6790 / 5673 / 1117

4:52 P.M. 1 olt. at 4:38 P.M.

(2) 835.0 + 13.2
(3) 837.0 + 13.6
(4) 816.5 + 15.2
(5) 836.0 + 13.1
(6) 836.5 + 13.0
4167.0 + 69.5 = 4236.4
4234.5

G	F	No 17 (3.4)
~~29.024~~		
29.032	20.910	$\frac{1}{20.91}$ = .04783
(28.9)	(21.0)	
29.136		
29.176	91.2	$\frac{1}{91.2}$ = .01096
29.204	49.5	$\frac{1}{49.5}$ = .02020
29.172	(39.2)	?
29.030	34.6	
29.148	34.4	$\frac{1}{34.4}$ = .02907
29.114	91.0	$\frac{1}{91}$ = .01099
29.010		
1/10 22		
29.114		

.03687 / 4 = .009218

.00924 ÷ .00924

.00887 : 1 = .00887

.01808 / 2 = .009040

9218
9240
887
9040
4/36364
.009092 from differences

.3434 / 1094 / 5/.04533 / .009066
3434 / 2899 / 7/6333 / 9048
3434 / 2020 / 6/5454 / 9090

3434 / 1096 / 5/4530 / 9060
3434 / 4783 / 9/8217 / 9130

9066
9048
9090
9060
9130
5/394
9079

5:13 P.M.

$\frac{1}{29.114}$ = .03434 × 1031 = .03506 = v_1

Log = −2.5448

$\frac{1}{2}$ " = −1.2724

.009080 × 1031 =

$v_1 + v_2$ = .0092707

Log = −3.9671
−1.2724
−3.1983
−6.4378 Vol = 4234
3.6264
−10.8114

e_1 = 6.478
6.479

a:
−16.4270
−3.6267
−2.5448
3)−14.5985
−3.9671
3)−12.6314
−4.2105
1.2348
−3.4453
2.5547

l = .00004168
−4.8547
1.2348
−5.6199
−4.2105
−1.4094

.2567 = l/a

.0001624 = a
1619
1616

3567 = 1/pa
360.0
360.6

where e_1 =
e_1 = 6.478
e_1 = 6.466 (chosen above)

$e_1^{2/3}$ = 3)−10.8111
−4.9370
2
−7.8740
74.81
74.77 final avg 2-3

8106
2
16212
7.8737

(6) Fourth Obs. Mar 14, 1912 $\theta = 23.09$ $p = $ 6856 − 5001 = 1855; 6853 − 5000 = 1853

Volts at 5:15 P.M.
(2) 833.5+13.6
(3) 835.0+13.2
(4) 816.0+14.5
(5) 834.0+13.8
(6) 834.5+13.4
4152.0+68.1 = 4220.1
(1) 829.5+14.2
4981.5+84.6 = 5066.0

Volts at 5:45 P.M.
(1) 828.0+14.2
(2) 833.5+13.9
(3) 833.5+13.9
(4) 814.5+15.3
(5) 833.0+13.9
(6) 833.0+13.9
4976.4+85.1 = 5061.6

G		F
13.170		28.506
13.126		
13.140		
13.120		
~~5:55 P.M.~~		
6:00 PM		
	22.2	44.4
21.344		31.992
		32.116
	(16.2)	(32.2)
21.186	36.3	72.9
21.250		44.766
21.290		32.288
21.088	22.6	45.4
21.180		32.720
21.006		45.4
21.060		45.354
21.172		(45.4)
20.938		76.0
9)190170		
21.130		

No 18
33

$\frac{1}{32.1} = .03115$; $\frac{.01726}{2} = .00863$
$\frac{1}{72.0} = .01389$; .00845
$\frac{1}{44.77} = .02234$; .00863
$\frac{1}{32.29} = .03097$; .00874
$\frac{1}{45.4} = .02203$; .00853
$\frac{1}{32.72} = .03056$; .00851
$\frac{1}{45.35} = .02205$; .00889
$\frac{1}{76.0} = .01316$; 7)6058 .008654

at 6:30 P.M.
828.0+14.3
832.0+14.0
833.0+13.9
814.0+15.0
832.0+14.0
832.0+14.3
4971 + 85.5 = 5056.5

4732 + 1316 → 7)06048 .008640
4732 + 2205 → 8)6937 .8671
4732 + 3056 → 9)7788 .8653
4732 + 2203 → 8)6935 .8669
4732 + 3097 → 9)7829 .8699
4732 + 2234 → 8)6966 .8707
4732 + 1389 → 7)6121 .8744

844, 8671, 8653, 8669, 8699, 8707, 8744 → 7)4783 .008683

.008683 × 1.021 = $v_1 + v_2$ = .0088653

$\frac{1}{21.13} = .04732 \times 1.021 = v_1 = .04830$

log = −2.6839
log = −1.3420

6:30 P.M.

a
−16.4270
+3.7040
−2.6839
−14.8149
−3.9477
3)12.8672
−4.2891
1.2681
−3.5572
2.4428

$l = .00003860$
−4.8347
1.2681
−5.5866
−4.2891
−1.2975

.1846 = a
1848
33

.1984 = $\frac{l}{a}$
1990

277.2 = $\frac{1}{pa}$
2780

log = −3.9477
−1.3420
3.1983
−6.4880
+3.7040
10.7840

6081
5058

$e^{2/3}$
2)14.7841
−4.9280
7.8564

e_1 = 6083

$e^{2/3}$ = 71.80

e_1 = 6076
$e^{2/3}$ = 7172
final

e_1 = 6074
(from corr.
reduced) $e^{2/3}$ = 7173

Friday March 15, 1912

$\theta = 23.05$ p = 6837 / 4976 / 1901

Voltbat 3:50

No 19

32

G	F	
4:15 P.M.		
	33.4	68.4
24.016		42.188
	(21.0)	(42.4)
24.142		42.078
		(42.2)
24.130		42.098
	(21.2)	(42.3)
24.070	34.6	69.9
24.000	100.8	203.2
24.030		23.844
24.046		30.606
24.028	22.0	42.8
23.968		42.944
		(43.0)
24.018		71.4
23.770		~~31.460~~
23.882		30.652

12 | 481.00
24.008

4:47 P.M.

1/42.19 = .02373

1/42.3 = .02364 } .00933

1/69.9 = .01431 } .00939

1/203.2 = .004921 } .03779/4 = .009257

1/23.84 = .04195 } .00927

1/30.6 = .03268 } .00938

1/42.944 = .02329

} .00925

1/71.4 = .01400 } .01869/2 = .00929

1/30.65 = .03263

differences

933
934
937
9257
939
925
929
7 | 6477
.009311

839.5 + 14.2
834.0 + 13.8
836.0 + 13.6
815.0 + 15.2
834.0 + 13.8
834.0 + 13.8
4992.5 + 84.4
= 5066.9

9280
9283
9279
9293
9290
9316
9328
9341
5 | 46410
9301

.04166 / 3269 / 8 | .07425 / .009281 / 94

4166 / 1400 / 6 | .5566 / 9277

4166 / 3268 / 7 | 6498 / 9276

4166 / 3265 / 4 | 7431 / 9289

4166 / 4195 / 9 | 8361 / 9286

4166 / 4900 / 5 | 46566 / 9316

4166 / 1431 / 6 | 5597 / 9328

4166 / 2369 / 7 | 6535 / 9336

mean = .009304 × 10⁻² = [illegible]

$v_1 + v_2$ = .09496

1/24.01 = .04166 × 1021 = .042534 = v_1

log = −2.62873
$\frac{1}{2}$ log = −1.3149

ℓ = .0000 9764

a

−4.4270
3.7044
−2.62873
−14.7601
+3.9796
3 | 12.78285
−4.26068
1.2790
−3.5398
2.4802.

−4.8547
4.2790
−5.5757
−4.2608
−1.3149

.2065 = ℓ/a
2073

.000182 = a
1810

2885 = 1/Pa
2898

log = 3.9796
−1.3149
−3.1963
−6.4808
3.7044
−10.7864

5062 × 1

A 6116

e_1 = 6117

$e^{2/3}$

−17.865
3 | −19.5820
−7.8578

7860
3 | 57.86
7.8578
72.03

e_1 = 6110
72.03

e_1 = 72.17
72.10

Error 2%

Beauty

Publish this surely
beautiful

Friday March, 15, 1912

Second Observation

5:00 PM.

$\theta = 23.13$

Volts at 4.49

$p = \frac{6890}{4955}$ 19.35

8280 + 14.3
8380 + 13.9
8340 + 13.8
814.0 + 15.3
832.5 + 14.0
832.5 + 14.0
4974.0 + 85.3 = 5059.3

G		F
15,050		~~14.924~~
14.904		11.886
14.878	(16.4) (33.2)	33.254
14.968	(33.3)	33.132
14.956		43.526
14.868	(57.2) (43.8)	43.768
14.912	(47.3) (33.6)	33.386
		33.594
14.912		
14.822	57.1	114.0
8) 7220 14.903		

5:35 PM

$\frac{1}{14.903} = .06710$

$\frac{1}{11.89} = .08413$

$\frac{1}{33.19} = .03013$

$\frac{1}{43.65} = .02291$

$\frac{1}{33.49} = .02986$

$\frac{1}{114.0} = .008772$

Differences

$\frac{.05400}{8} = .00677$

.00722

.00695

$\frac{.02104}{3} = .007030$

679
695
722
703
4) 2799
.006992

6710
8772
11) .075872
.06900

6710
2986
14) 9696
6922

6710
2291
13) 9001
6923

6710
3013
14) 9723
6945

Error high will not use

Can work through + partly … but … not important … if … time …

9.

Friday, March 15, 1912. $\theta = 23.09$ $p = 19.73$

Third Observation — Volts at 5:37

at 5:55 P.M

7070 (31)

G		F	
	65.2	130.4	$\frac{1}{130.4}$ = .007669
20.026		31.140	$\frac{1}{30.4}$ .03211
19.978		15.322	
19.930		13.662	
20.032		13.762	$\frac{1}{13.71}$ = .07294
19.986	68.0	136.0	$\frac{1}{137}$ = .00729
19.978	—	138.5	
19.986	32.0	65.2	$\frac{1}{65.1}$ .01536
19.900	—	65.0	
19.972		42.482	$\frac{1}{42.48}$ .02354
19.826	(21.4)	(42.3)	
	32.0	65.0	$\frac{1}{65.0}$ .01538
19.931		31.774	$\frac{1}{31.77}$ .03148
19.888		30.264	$\frac{1}{25.46}$ .03960
239.933		(25.4)	
19.961			

.02444 / 3 = .008147

.04463 / 5 = .008166

.06565 / 8 = .008206

.00807 / 1 = .00807

.00818 / 1 = .00818

.00816 / 1 = .00816

.01610 / 2 = .00805

.0812 / 1 = .0812

Volts at 6:25 P.M.

822.0 + 14.3
832.5 + 14.0
834.0 + 13.8
814.0 + 15.3
832.5 + 14.0
832.5 + 14.0
4973.5 + 85.4 = 5058.9

827.0 + 14.4
831.5 + 14.1
832.0 + 14.0
813.5 + 15.4
831.0 + 14.1
831.0 + 14.1
4966.0 + 86.1 = 5052.1

847
8166
8206
8070
8180
8160
~~8050~~
~~8120~~
6) 48921
.008155

~~8050~~
~~8120~~
8185
8184
8185
8201
8204
8225
6) 11885
8198

differences

.5010	5010
3160	3148
11) 8972	19) 8160
8157	8160
5010	5010
1536	2354
5) 6546	9) 7364
8185	8182
5010	5010
1536	729
4) 6546	7) 5739
8185	8199
5010	5010
7294	3211
15) 12304	10) 8221
8202	8221

6:25 P.M.

$\frac{1}{19.95}$ = .05010 × 1.021 = v_1 = .05115

Log = −2.7088

v_1 = −1.3544

a	l
−16.4270	−4.8549
7.7036	1.2452
−2.7090	−5.5543
−14.8396	−4.3056
−3.9227	−1.5529
3) −12.9169	
−4.3056	
1.2452	
−3.6008	
2.3992	

.1799 = $\frac{l}{a}$

.1999

.0002027 = a

2012

2507 = $\frac{1}{pa}$

2518

$v_1 + v_2$ = .03895 × 1.021 = .03977

Log = −3.9227
−1.3544
−3.1983
−6.4754
3.7036
−10.7718

5054 = V

$e^{2/3}$

5913

e_1 = 5.916

e_1 = 5910

−10.7720
3) −19.5 4940
−2.8480

$e^{2/3}$ = 7041

$e^{2/3}$ = 7047

Weighting ... brownian ... light ... for ... [illegible]

10) Saturday March 16, 1912 - θ = 22.97 f =

at 3:30 P.M. 831.0 + 14.1
836.5 + 13.6
837.0 + 13.5
817.0 + 15.1
836.0 + 13.6
836.0 + 13.6
4993.5 + 83.5 = 5077.0

G	F	
	683	10921

4:05 P.M.

G		F
16.714		20.692
16.478		135.4
16.502	67.6	134.5
16.542		Balance speed
4 | 22.36		
16.559		

$\frac{1}{20.64} = .04833$

$\frac{1}{135} = .007407$

$\frac{1}{1656} = .06039 \times 1021 = v_1 = .0616$

Log = −2.7900

$\frac{1}{2}$ = −1.3950

W₀ = 1.0923
68.20

6039
7407
16 | 67797
.006780

6039
4833
16 | 10872
.006795

mean = .006796 × 1021 = .06939

Log = −3.8413
−1.3950
−3.1983
−6.4346
+3.7048
10.7298

V = 5068

e₁ = 5.368

a
−16.4270
3.7048
−2.7900
−14.9211
−3.8413
3 | 11.0805
−4.3602

.002292 = a

Can't get β

$e^{2/3}$
10.7298
2
3 | −19.4596
7.8199

66.055 = $e^{2/3}$

Second Observation $\theta = 22.98$ $p = \frac{77.90}{-26.5}{33.95}$ [sic]

Saturday, March 16, 1912 —

4:30 P.M.

Volts at 446 —
829.5 + 14.2
833.5 + 13.9
834.5 + 13.7
814.5 + 15.3
833.5 + 13.8
833.5 + 13.8
4979.0 + 84.7 = 5063.7

No 21 (= 6430)

G	F.	
	11.886	.06413
15.172	96.4 —	.01037
15.172	11.808	.05468
15.066	33.544	.07968
15.210	33.878	
15.160	59.5 —	.01681
15.150	23.667	.04224
15.174		
7) 1.1800		
15.157		

46.4

}.01931 / 3 = .006437

}.01300 / 2 = .006500

}.02543 / 4 = .006357

3) 1289
.006430

4:45 P.M.

1/15.157 = .06598 × 1.021 = .067365 = v_1

Log = -2.8284

Log = -1.4142

6598 / 4044 / 17) 10822 / 6366
6598 / 1681 / 14) 8279 / 6364
6598 / 2968 / 15) 9566 / 6371
6598 / 1037 / 12) 7635 / 6363

6363
6364
6366
4) 1289
6367

mean { 6430 + 6367 = 006399

mean $v_1 + v_2$ = 006337

Log = -3.8151
-1.4142
3.1983
-6.4276
3.7047
-10.7229

V = 5066

a

-16.4270
3.7047
-2.8284
-14.9601 [sic]
-3.8151
3) -11.1450
-4.3817
1.5405
-3.9222
-2.0278

-4.8547
1.5405
-5.2642
-4.3817
-3.8824

.07626 = 1/a
3600

.002412 = a
2409

1066 = 1/ka
1072

$e_1 = 5.284$

$e = 5.278$

$e^{2/3}$
-10.7229
2
3) -14.4454 [sic]
-7.8151
6.533 = $e^{2/3}$
65.28

Pretty reliable here.

16

17 Third Observation
Saturday, Mar. 16, 1912

5:05

$\theta = 22.93$

$p = 74.15$, 37.50, 41.65

Volts at 5:29 P.M.
829.0 + 14.2
833.0 + 13.9
834.0 + 13.8
814.0 + 15.3
833.0 + 13.8
833.0 + 13.8
4976.0 + 84.8 = 5060.8

G		F	
33.682		19.908	
33.822		19.922	
33.666	(16.6 / 33.6)	19.830	1/19.87 = .05033
		19.818	
33.486		24.862	
33.634		24.628	(24.6) 1/24.8 = .04032
33.500	(33.4)	24.910	(24.6)
33.514		49.744	(49.9 / 49.6) 1/49.74 = .02010
33.530	(17.0 / 33.6)		
6 / 44.34			
33.604			

5:27 P.M.

.01001 / 1 = .01001

mean .01006

.02022 / 2 = .01011

.02976, .05033, 6 / .08009, .01001

.02976, .04032, 7 / .7008, 10011

10011, 9972, 3 / .29994, .01000

2976, 2010, 5 / .4986, .009972

$v_1 + v_2 = .01021$

Log = −2.0090
−1.2413
−3.1963
−6.4466
−3.7043
10.7443

No 22

1/3360 = .02976, 1/1038 = .030385

Log = 2.4826

1/2.11 = .12413

a	l
−16.4270	−4.8547
3.7043	1.6196
−2.4826	−5.2351
−14.6139	−4.2016
−2.0090	−1.0335
3 / −12.6049	
−4.2016	
1.6196	
−3.8212	
2.1788	

.0001591 = a

.1080 = l / a

150.4 = 1 / pa

5.550 / 2

e_1 = 5.548

reduce for ch[illegible] to e_1 = 5.537

$e^{2/3}$
10.7441 / 2
3 / −19.4882
7.8294

67.50 = $e^{2/3}$
9
6.248

Too high e by 1/2 %

[illegible]
for [illegible]

Found atomizer out of order
Took apparatus apart + reset up
entirely
Not plotted but may[illegible]

(13) Wed. March 20 1912 $\delta = 23.01$ $\phi = \frac{7476}{4270}\ \frac{7475}{4269}$ $\frac{}{32.06}\ \frac{}{32.06}$

Volts at 2.50 P.M.

834.0 + 13.8
839.0 + 13.3
839.0 + 13.3
818.5 + 15.1
839.0 + 13.3
837.5 + 13.5

Volts irregular loose contact? battery connections

5007.0 + 82.3 = 5089.3

G	F		S	F	
9.842					
9.942			9.852	32.6	68.4
9.926					
9.930		23.608			
9.878		21.906			
		23.096			
9.960		23.610			
9.854		35.876			
9.904		38.614			
9.824		38.806			
9.806		(35.6) 39.244			
	(19.3)	(39.2)			
9.900		41.812			
9.866		(42.0) 40.032			
	19.4	(40.2)			
9.900		38.766			
9.954		40.390			
	(20.6)	(40.4)			
9.860		37.466			
	(18.0)	(36.4)			
9.964		39.088			
	(18.6)	(39.0)			
9.942	11.2	22.6 —			
9.888		22.292			
	(11.0)	(22.2)			
9.872					
9.966		76.836			
	(37.0)	(77.0)			
	33.0	66.4 —			
	26.7	57.6 —			
9.896	32.4	65.0 —			

(4)

Wed. Mar. 20th 1912

θ = 22.99

$p = \frac{75.40}{41.93}$ 33.47 ; 75.38 − 41.93 = 33.45

Second Observation 4:45

Volt at 4:25

832.0 + 14.0
837.0 + 13.5
838.0 + 13.4
817.5 + 15.1
837.0 + 13.5
837.0 + 13.5
4998.5 + 83.0 = 5081.5

8333
8342
8256
3) 931
8310

No 22 (29)

G		F
23.184		
23.230		
23.420		24.730
23.302		17.586
23.344		17.600
23.194		17.624
23.228		20.606
23.210		146.4 —
	75.0	− 1st div.
	87.0	− 2nd div.
23.110		42.768
	(21.2)	(42.5)
23.202		42.448
23.068		42.718
23.158	73.0	145.4 —
23.244	73.2	144.6 —

13) 2894
23.223

$\frac{1}{24.73}$ = .04044

$\frac{1}{17.603}$ = .05682

.00883

$\frac{1}{20.6}$ = .04854

$\frac{1}{146.4}$ = .00683

$\frac{1}{65.0}$

$\frac{1}{42.645}$ = .02348

$\frac{1}{145}$ = .006897

.01653 = 8256

4944 = 8333

8256
16589
.08260

4303
3897
6) 49927
.008321

4303
5682
12) 9985
8321

4303
4545
6) 6644
8301
8315

4303
663
4966
8310

8326
8323
8118
.08393

8328
8310
8301
8321
8313

mean of 8304, 8302 = .008312

$V_1 + V_2$ = .008313 × 1021 = .008495

Log = −3.9288
−1.32148
2.1999
−6.44995
5079.3 V = −3.70537
−10.74350

5:35 PM

$\frac{1}{23.24}$ = .04303 × 1021 = .04393 = V_1

log = 2.6428

$\frac{1}{2}$ = 7.3214

a

−16.4209
3.7053
−2.6426
−14.3590
−3.9288
3) −12.8402
−4.2801 = .0004474 = a
1.5246
−3.8049
2.1955

1908

l

−4.8547
1.5245
−5.3302
−4.2820
−1.0482

.1117 = $\frac{l}{a}$

.1120 = $\frac{8l}{a}$

1561 = $\frac{l}{pa}$

1568

e_1 = 5.539

Corr for ... e_1 = 5.538

−10.74385
2
3) 14.48776
−7.82925

67.485 = $e_1^{2/3}$

67.40 (33)

~~65.9~~

Error 4%

e_1 = 5538

7426
3) 17.4852
−7.8284

$e_1^{2/3}$ = 67.34

Lippmann buf
might publish

Wednesday, Mar. 29 1912

Third Observation

5:48

$\theta = 23.09$

Volts at 5:40

$p = \frac{7555}{4178} \frac{7552}{4178}$

$\frac{}{33.78} \quad \frac{}{2374}$

830.5 + 14.2
835.0 + 13.6
836.0 + 13.6
815.5 + 15.2
834.0 + 13.8
833.0 + 13.9

4984.0 + 84.3 = 3068.3

G	F	
5.660	45.2 —	
5.694	45.2 —	$\frac{1}{45.4} = .022103$
5.654	45.4 —	
5.652	45.4 —	
5.666	20.4 —	
5.678	20.4 —	$\frac{1}{20.4} = .044402$
5.622		
~~5.676~~		
~~5.622~~		
~~5.651~~	20.530	
5.656		
5.700	20.578	
4 | 59.80		
5.653	6:03 P.M.	

$\frac{1}{5.653} = .1769$

.02649 ÷ 7 = .003856

Corrected diameter

.1769
2208
.1990

Wednesday Mar. 20, 1912   θ = 23.06   p = 7563 − 4162 = 3401; 7563 − 4161 = 3402

Fourth Observation
6:27 P.M.

Volts at 6:05

G	F	
37.912		
38.018	25.118	$\frac{1}{25.12}$ = .03981
37.938		
(38.0)	19.686	$\frac{1}{19.69}$ = .05079
38.200		
(38.2)	16.168	$\frac{1}{16.17}$ = .06184
37.998		
38.012	149.0	$\frac{1}{149}$ = .006711
38.102	56.8	$\frac{1}{56.8}$ = .01761
37.910		
8)304080	6:45 P.M.	
38.01		

.02098 / 2 = .01050
.01105
.05513 / 5 = .01103
.01090

Volts at 6:46

23 (circled)   28

830.5 + 14.2
835.0 + 13.6
836.0 + 13.6
815.5 + 15.2
834.0 + 13.8
832.0 + 14.0
4983.0 + 84.4 = 5067.4

830.0 + 14.2
832.0 + 14.0
832.0 + 14.0
815.0 + 15.2
833.5 + 13.9
831.5 + 14.1
4974.0 + 85.4 = 5059.4

mean of = .01097

2627 − 1761 = 4)4388 = .01097
2627 − 671 = 2)3298 = 1.099
2627 − 6184 = 5)5511 = 1102
2627 − 5079 = 7706 = 1101   mean = 11005

mean of 1097 + 1092 = 1.098 × 1021 =

$\frac{1}{38.01}$ = .02627 = .02682 = v

corrected from furnace   Log = −2.4284
$\frac{1}{2}$ = −1.2142

$v_1 + v_2$ = .011205
Log = −2.04933
$\frac{1}{2}$ = −1.2142
−3.1983
−6.4617   5061 = V
3.7043
−10.7574

e = 5720

e_1 = 5721

~~reduced to get ...~~
e_1 = ~~5727~~
e_1 = 5714

$e^{\frac{2}{3}}$
−10.7584
3)−19.5178
−7.8392
6906
6895

7564
3)415155
−7.8379
6884

1 / 10

Error 3%

1
−4.8547
1.5316
−5.3231
−4.1699
−1.1532

a
−16.4370
3.7042
−2.8291
−14.5603
−2.0506
3)−12.5097
−4.1699   .001429 a
1.5316   .1429 a
−3.7015
−3.2985

.1423 = $\frac{l}{a}$
.1429 = $\frac{b}{a}$

1.485 = $\frac{l}{pa}$ 1998 = $\frac{1}{pa}$

Publish

Beauty

21

(1) Monday, Mar. 25th 1912   θ=23.19   p= 7617/4100/3517 7617/4099/3518

voltmeter 3:30 PM.

837.5+13.5
836.5+13.6
841.0+13.2
824.0+14.7
840.0+13.2
841.5+13.2
5020.5+81.4=5101.9

3:42 P.M.

(24) (27)

G	F
26.860 (blot)	
27.066	19.252
26.782	19.388
26.958	16.292
27.142	11.360
26.874	39.424
26.860	39.306
	60.824
(30.0)	(60.8)
26.906 64.6	134.0
26.578	39.670
26.814	39.728
(19.6)	(39.7)
26.632	39.458
	(39.6)
26.598 67.4	138.4
26.706	

13) 348.794
26.83

4:13 PM.

1/19.320 = .05176

.02636/3 = .08790

1/39.365 = .02540

.008950

1/60.8 = .01645

.008987

= .007463

.01778/2 = .008890

1/39.62 = .02524

.01802/2 = .009010

.00722

$\frac{1}{26.83}$ = .03727 x 1021 = v_1 = .03801
3723

Log = 2.5999
1/2 = -1.2999

Diff
.08790
8950
.8987
8890
9010
5)44627
.008925

.03723
722
5).04445
.008890

3723
7462
5)44693
8939

3723
2224
7)62267
8924

3723
1645
5)45368
8947

3723
2540
7)6263
8947

3723
5176
10)8899
8899

8890
8924
8939
8947
8947
8899
6)5346
.008925 x 1021 =

v_1+v_2 = .009112
Log = -3.9596
-1.2900
-3.1477
6.4473
3.7067
-10.7406

V = 50895

a   l

-4.8547
-16.4127009 1.5460
3.7067467 -5.3087
-2.5804198 4.2475
-14.7141076 -1.0994
-3.4118586
3)-12.8025480
-4.2674493
1.5463
-3.8137
2.1863

.1099 = l/a
1199 = a
.0001651 = a
1645 = a
.777
133.6 = 1/pa
1520 = 1/pa

2493
5460
7953
2097
1602 = 1/pa

5508
4
e_1 5508
~~Reduced for~~
~~Chem corr~~
e_1 = 5.513
e_1 5505
e_1 = 5507

$e^{2/3}$
-1.7420
2
3)19.4840
-7.8280
67.30 = $e^{2/3}$
66.13
$e^{2/3}$ 6718
= 6718
avg 3rd

1409
2.4818
7.8273
6737

Brevity
Publish

Mon. Mar. 25, 1912

Second Observation -
4:44. P. M.

$\theta = 25.21$
23.14

$\phi = \frac{7685}{4019}\ \frac{7643}{4020}$
$\frac{3665}{3662}$

Volts at 4:15 P. M.

836.5 + 13.6
832.0 + 14.0
839.0 + 13.3
822.5 + 14.8
838.0 + 13.9
838.0 + 13.4

5001.0 + 82.0 = 5083.0

G		F	
34.068		31.136	
	(16.0)	(31.4)	→
34.324	83.0	1st Division	
	94.4	2nd "	
	76.6	3rd "	
	77.4	4th "	
	83.2	5th "	
	91.0	6th "	
	104.7	7th "	
	102.5	8th "	
		697.8 —	
34.062		86.382	→
	(44.0)	(86.7)	
34.008		86.4 —	
34.148			
		5:08 PM.	

Could work out but useless to do

19) Mon. Mar. 25, 1912 $\theta = \frac{23.18}{23.14}$ $p = \frac{77.09}{39.90}$ 37.14

5:24 (Third Observation) Volts at 5:08 P.M.

G		F	
12.394			
12.448		12.246	
12.452		12.248	$\frac{1}{12.273}$ .08151
12.490		12.326	
12.472		21.154	
12.488		24.282	
12.456		24.248	
12.466		24.242	$\frac{1}{24.231}$ = .04127
12.514		24.152	
12.480		55.5 —	
12.484		55.416 (55.6)	$\frac{1}{55.6}$ = .01805
12.442		81.3 —	$\frac{1}{81.3}$ = .01230
12.458	40.0	81.3 —	
12.364		21.3 —	$\frac{1}{21.25}$ = .04706
	(10.6)	(21.2)	
12.430		24.270	
	(12.6)	(24.1)	
12.536		24.194	$\frac{1}{24.283}$ = .04118
12.460		24.304	
12.442		24.264	
12.462		155.022	$\frac{1}{155}$ .006458
12.468	79.4	155.9 —	.006414
12.698		55.8 —	
12.498		55.782 (55.8)	$\frac{1}{55.8}$ = .01792

24) 103.84 / 12.466

$\frac{1}{12.466}$ = .08021; $x_1 \cdot x_2$ = .081894 = x_1

Log = −2.91838

$\frac{1}{x_1}$ = −1.4568

6:00 P.M.

$\frac{.04024}{7}$ = .5749

$\frac{.02322}{4}$ = .5800

.00575

$\frac{.03476}{6}$ = .5793

$\frac{.034566}{6}$ = .5761

$\frac{.011506}{2}$ = .5753

25

26

835.0 + 13.6
830.5 + 14.2
835.0 + 13.6
822.0 + 14.8
830.0 + 14.2
838.0 + 13.4

4990.5 + 83.8 = 5073.3

Differences

5749	.080234
5800	1792
5800	17 / .098154
5750	.005774
5750	
5793	.080234
5793	6414
5793	17 / .086648
5740	.005776
5761	
5761	.080234
5761	.04114
5761	21 / .121414
5753	.005781
5753	
5753	.080234
17 / .13124	.01230
.005778	16 / .092534
	.05783
.080234	
.01805	
17 / .09828	
.005781	5778
	5778
.080234	5779
4827	5763
21 / .12144	5779
.005784	5784
	5775
.080234	4 / 558
.8151	.0057790
14 / .16179	
.005777	

$v_1 + v_2$ = .005779 × 1021 = .005880

Log = −3.7705

−1.4566

3.1977

−6.4248 v_1 = 5050

3.7038

−10.7215

a

−16.4270
3.7039
−2.4134
−12.0437
−3.7709
3 / −11.2739
−4.4240 .2655 = a
1.5795
−3.9945
2.0058

2644 = c

l

−4.8547
1.5704
−5.2848
−4.4248
−2.8693

.07248 = $\frac{l}{a}$

.0724 = $\frac{l}{a}$

101.2 = $\frac{1}{pa}$

101.8 = $\frac{1}{pa}$

$e_1^{2/3}$ = .6534

e_1 = 4.76

$e_1^{2/3}$

72332

2.44664

−2.61555

5.2

Publish this one

Error say 2%

30/ Mon. Mar. 25, 1912

Fourth Observation

6:18 P.M.

G		F
8.504		15.490
8.502		16.922
8.532		16.812
8.526		16.714
8.524		16.914
8.332	(19.0 / 37.4)	37.308

Lost at 6:27

θ = 23.15

Volts at 6:00 P.M.

p = 7748
3947
38.01

832.0 + 14.0
817.0 + 15.1
830.5 + 14.2
816.0 + 15.2
821.5 + 14.8
834.0 + 13.8
4951.0 + 87.1 = 5038.1

Volts at 6:28

829.5 + 14.2
809.5 + 15.6
829.5 + 14.2
814.0 + 15.3
819.0 + 14.9
830.5 + 14.1
4932.0 + 88.3
= 5020.3

Impossible to work out

7223
.114446
8.8148
6539 = c?

Tuesday Mar. 26th 1912   θ = 22.89

First Observation

Volts at 3:40 P.M.

$p = \frac{77.70}{38.19} \; 38.51$

837.0 + 13.5
841.5 + 13.2
841.5 + 13.2
821.5 + 14.8
840.5 + 13.2
840.0 + 13.2
5022.0 + 81.1 = 5103.1

G		F
38.590	71.6	145.4
38.670		56.234
	{28.4 / 56.5}	
38.458		65.768
38.376	{17.6 / 34.4}	34.418
38.358		34.552
38.530		65.956
38.372		
7)33354		
38.479		

$\frac{1}{145.4} = .006878$
} .01095
$\frac{1}{56.17} = .01783$
} .01112
$\frac{1}{34.64} = .02895$
.01117
$\frac{1}{56.07} = .01784$
.03318
.01106

.02595 / .01784 / 4)4379 / .01095
.2595 / .3895 / 5)5490 / 1098
.2595 / 1753 / 4)4378 / 1094
.2595 / 1388 / 3)3283 / 1094

1094
1098
1543
1095

mean = .01095 / 1041

$= v_1 + v_2 = .01116$

Log = −2.0482
1.2115
2.1997
6.4594
3.7074
−10.7591

V = 5098

4:15 P.M.

.02595 × 1021 = .026495
Log = 2.42305
½ = 1.21152

a
−16.427009
3.707474
−2.423830
−14.558013
−2.049082
3)−12.5099
−4.1697
1.5856
−3.7552
2.2448
2467

l
−4.8547 = const
1.5856
−5.2691
−4.1696
−1.0995

.1257 = $\frac{l}{a}$
.1263

.001478 = a
1478 = a
1477

$17.57 = \frac{1}{pa} = 17.65$

5625
3
5622
reduced for chamber
e_1 = 5.628
e_1 = 5.621

$e^{2/3}$
10.7525
2
3)19.5030
−7.8346
6828
10
6818
6812 = $e^{2/3}$

107500
2
3)195000
7.8333

No 16

~~23~~

25

Can Publish

The values e_1 = 5.142, e_1 = 6.419

a wrong? .05% for taken from ... ...

28) Tuesday Mar. 26th 1912. θ = 23.00 p = 79.17 / 37.40 / 41.77

Second Observation

4:57 P.M.

Volts at 4:16

Note:– Middle point between plates should be at 10538–

G		F
9.452		
9.462		12.156
9.476		20.842
9.466		30.856
9.454		26.338
9.474		26.200
9.396		26.230
9.470		30.206
9.450	(35.2)	35.548
9.516		35.606
9.452	38.2	76.2—
9.434	37.6	75.4—
9.498	——	75.2—
9.519	(19.0)	18.830
9.518		18.780
9.544		18.876
		35.358
9.492		35.442
9.486		35.478
9.544		121.9—
14) 91.53	61.0	121.5—
9.480		

5:30 P.M.

Volts at 5:31

$\frac{1}{20.85}$ .04797 — $\frac{.00989}{2}$ = 4945

$\frac{1}{26.26}$ = .03808 — $\frac{.01990}{4}$ = 4975

$\frac{1}{35.58}$ = .02807 — $\frac{.01484}{3}$ = 4947

$\frac{1}{75.6}$ = .01323 — $\frac{.03988}{8}$ = 4985

$\frac{1}{18.83}$ = .05311 — $\frac{.02492}{5}$ = 4984

$\frac{1}{35.42}$ = .02819 — $\frac{.19973}{4}$ = 4993

$\frac{1}{121.7}$ = .00821

51334

4967

mean v_1+v_2 = .004954 × 1.021

= v_1+v_2 = .005058

log = –3.7040
–1.5166
–3.1983
6.4189
2.7070
10.7119

5.151
5.145

$\frac{1}{9.480}$ = .1055 × 1.021 = v_1 = .1077

log = –1.03222

$\frac{1}{2}$ = –1.5166

836.0 + 13.1
840.0 + 12.7
840.0 + 12.7
820.5 + 14.7
840.0 + 12.7
839.5 + 12.7
5016.0 + 78.6 = 5094.6

835.0 + 13.2
839.5 + 12.8
839.5 + 12.8
820.0 + 14.7
839.0 + 12.8
839.0 + 12.8
5012.0 + 79.1 = 5091.1

Difference
.005000
.005000
.005000
4976
4985
4985
4983
4980
4985
6) 29.851
.004983

1055 / 1333 / 24) 11673 / 4942

1055 / 822 / 23) 11372 / .4971

1055 / 2823 / 27) 13373 / 4952

1055 / 5311 / 32) 15861 / 4957

1055 / 5811 / 37) 18361 / 4949

1055 / 3808 / 29) 14358 / 4951

1055 / 4993 / 32) 15847 / 4956

4971
4952
4957
4948
4949
4951
4956
7) 34799
4957

Each of differences but 4963 & 4954 use the mean. These are nearly just the same in value, ... 4963 ... corrected so as to hit ... 38%

$e^{2/3}$
–10.7133
3) 14.42 66
7.8089

$e^{2/3}$ = 6440
6435

a
–164270
3.7070
–1.0322
13.1662
–3.7054
3) 11.4608
–4.4869
1.6208
–2.1077
–1.8923

l
–4.8547
1.6208
–5.2339
–4.4866
–2.7470
.05585 = $\frac{l}{a}$
.0003069 = a
7803 = $\frac{1}{pa}$

7114 / 3) 14.9228 / 7.8076

6422 = $e^{2/3}$

22

Beauty
Publish

Publish this fine determination of e ... sheet

~~Wednesday~~ ~~Tuesday~~ Mar. 27, 1917

First ~~Third~~ Observation at 4:35 P.M.

$\theta = 22.94$

Volts at 4:00 P.M.

$p = \frac{66.80 - 52.10}{14.70}$ $\frac{66.75 - 52.05}{14.70}$

837.0 + 13.5
842.0 + 13.1
840.5 + 13.2
2519.5 + 39.8 = 2559.3

(Publish this. 4% error about) (#3) Best ever. 3 rel. forms. Beauty

G		F
10.692		23.231
10.658		24.712
10.664		26.860
10.612		27.034
10.618		27.130
10.614		45.836
10.688	(31.6 / 63.6)	63.538
10.616	32.4	63.6 —
10.606	—	63.4 —
10.668	31.8	63.4 —
10.606	16.3	~~32.0~~
10.698		32.204
10.766	(32.0)	31.960
10.662	(23.0 / 45.6)	45.570
10.692	(23.2 / 46.0)	45.632
	(32.0 / 63.4)	63.130
10.704	(39.6 / 78.5)	78.352
10.626	39.6	78.0 —
10.708	(38.6 / 77.9)	78.032
10.574		274.3 —
12472	70.6 — 1+2 div	
10.6565	69.6 — 3+4 div	
	69.2 — 5+6 div	
	69.2 — 7+8 div	
		278.6 —

$\frac{1}{27.008} = .03701$
$\frac{.01522}{5} = .003044$
$\frac{1}{45.84} = .02178$
$\frac{.00607}{2} = .003035$
$\frac{1}{63.4845} = .01575$
$\frac{.01541}{5} = .003082$
$\frac{1}{32.058} = .03114$
$\frac{.00926}{3} = .003087$
$\frac{1}{45.601} = .02190$
$= \frac{.00609}{2} = .003045$ (3043)
$\frac{1}{63.13} = .01584$
$\frac{.00304}{1} = .003040$
$\frac{1}{78.128} = .01280$
$\frac{.00915}{3} = .003050$
$\frac{1}{274} = .003650$
4) .012188
.003054
Mean of diffs

.09384 + .2650 = 32) .09749 → 3044
9384 + 1280 = 35) .10664 → .3047
9384 + 1584 = 36) .10968 → 3047
9384 + 2143 = 38) .11557 → 3041
9384 + 3119 = 41) .12503 → 3050
9384 + 1575 = 36) .10959 → 3044
9384 + 3703 = 43) .13087 → 3044

3044, 3047, 3047, 3041, 3050, 3044, 3044, 3045.3

3057, 3050, 3050, 3040, 3040, 3045, 3047, 3088, 3088, 3035, 3042; 11) 635 → 3057

mean = 3045
$= 3045 \times 10^{-4} = .003149$
log = −3.4926
−1.4907
3.1483
−6.2816
3.4075
−10.7741
5.44
$e_1 = 5942$

a
−164270 4.2074 − 4.8547
3.4075 4075 1.1693
−2.9814 9814
−1.46159 ... 5.6874
−2.4430 ... −4.4408
3)1.3224 ... −1.2460
−4.4408 .002460 = a
1.1693 2799
−3.6081
2.3419 2466 = 1/ba

.17647
1764 / 71

$e^{2/3}$
−10.9988
3)1.4479
−7.8442
$e^{2/3}$ 7.0661

$\frac{1}{10.6565} = .09384 \times 10^{-1} = v_1 = .09581$
5:20 P.M. log = −2.9814, log = −1.4907

Wednesday, Mar. 27, 1912 θ = 22.94 p = 6723 − 5152 = 1571; 6722 − 5150 = 1572

Second Obs. 5:50 P.M.   Volts at 5.45 P.M.

834.0 + 13.8
840.0 + 13.2
840.0 + 13.2
2514.0 + 40.2
= 2554.2 = last obs.

Beauty Record.

for last obs. →

add for this obs.
820.0
14.9
839.5
13.3
4241.9

G		F
18.360		122.2
18.362		34.224
18.328		45.378
18.444		45.208
18.442		15.574
18.330		
18.330		17.468
18.428	34.0	66.0
18.390	(66.2)	66.020
18.174		122.6
18.388	(45.6)	45.414
18.392	(45.3)	45.282
18.240	(45.3)	45.110
18.314	(45.4)	45.282
18.324	61.6	121.6
18.312		121.2

16 | 5558
18.3474

$\frac{1}{45.293}$ = .02205 } $\frac{.04216}{6}$ = .007027

$\frac{1}{15.57}$ = .06421

$\frac{1}{17.47}$ = .05723 } $\frac{.04208}{6}$ = .007011

$\frac{1}{66.010}$ = .01515 } $\frac{.006993}{1}$ = .006993

$\frac{1}{122.6}$ = .008157

} $\frac{.013903}{2}$ = .006951

$\frac{1}{45.272}$ = .02206

} $\frac{.013852}{2}$ = .006925

.006925
5 | .034893
.006978

$\frac{1}{121.4}$ = .008238

mean def =

Volts at 6:30 P.M.

832.5 + 13.9
839.0 + 13.3
838.5 + 13.4
819.0 + 14.9
839.0 + 13.3
4168.0 + 68.8
4236.8

.05450
824
4 | .06274
.006971

5450 + 2206 = 11 | 7656 → 6963
5450 + 816 = 4 | 6266 → 6962
5450 + 1515 = 10 | 6965 → 6965
5450 + 2205 = 11 | 7655 → 6960

6971
6963
6962
6965
6962
5 | 34823
6965

6:30 P.M.

$\frac{1}{18.347}$ = .05450 × 1.021 = .05564

Log = −2.74542
$\frac{1}{2}$ = −1.37271

a
−16.42908
3.6271
−2.7454
−14.7994
−3.8519
3 | −12.9436
−4.3139
.1965
−3.5103
2.4898
4897

l
−4.8547
1.1965
−3.6542
−4.3139
1.3433

.2200 = l/a
.2210

.0002070 = a
2060

3076 = 1/pa
3088

Mult. v₂ = .006965 × 1.021 = .007110

Log = −3.8519
−1.37271
−3.1483
−6.4229
3.6271
−10.7958

v = 4238

e_1 = 6.249
$e^{2/3}$
−10.7957
16.5914
7.8698
$e^{2/3}$ = 7308

final e_1 = 6.249

Publish

Log
Log
$\frac{1}{\sqrt{R}}$ = .02724 $\frac{1}{R}$ = 3.447

Thursday 28th 1912 $\Theta = \frac{22.91}{22.83}$ $p = \frac{6347}{5592}{0755}$

First Obs at 3:37 P.M.   Volts at 3:08 P.M. 843.5+12.0
849.5+12.9
1693.0+24.9
=1717.5 volts

G	F	
28.45		
29.914		
30.052		
30.146		14.482
30.110		14.420
29.942		42.246
29.926 (short)		41.994
30.006		41.268
29.980		42.618
29.884	(28.6) (57.0)	56.228
29.954	(28.6) (56.4)	56.230
29.916	(28.6) (56.1)	56.176
29.908	(82.9)	82.878
30.124	(41.3) (83.2)	83.614
29.894		110.6 for 5 small div
14) 419.696		
29.978		

$\frac{1}{14.451} = .06920$ $\frac{.04554}{8} = .005699$

$\frac{1}{42.2815} = .02361$ 34 and

$\frac{1}{5568} = .02842$ $= .005670$

$\frac{1}{56.211} = .01776$ $= .005720$ 32 and

$\frac{1}{8300} = .1204$ $= .01199$

83.246 $\frac{11362}{2} = .5681$

$\frac{1}{8378} = .1193$ 4) 2280   .005690

$\frac{1}{1760} = .0005684$

.04554 / .005780 ; .03335 / .01199 / 8) .04534 / .005665 ; 3333 / 1776 / 9) 5109 / .005677 ; 3333 / 2361 / 10) 5694 / .005694 ; 5665 / 5677 / 5694 / 5695 / 4) 231 / .005683 ; 3333 / 6920 / 18) 10253 / 5695

$v_1 + v_2 = .005683 \times 1.021 = .005802$

Log = -3.7635
-1.26545
-3.19776
-6.22671
3.23320
10.99351   V=1711

- 9.853   Em corr

$.6855 = \frac{l}{a}$ $e_1 = 9848$

$e^{1/3}$
-10.9934
2
3) -14.9868
-7.9956

$99.00 = e^{2/3}$

4:03 P.M.

$\frac{1}{29.98} = .03335 \times 1.021$
$= V_1 = .03403$
Log = -2.5319
$\frac{1}{2}$ = -1.26545

a
-16.4289
3.2233
-3.5389
-14.1860
-3.7635
3) -12.4225
-4.1408
0.8779
-3.0187
2.9813

-4.8847
0.8779
-5.9768
-4.1408
-1.8360

.0001383 = a

$9578 = \frac{1}{pa}$

sk
-10.46136
3.2332
-7.69456
3.7635
-3.93106
-3.9312 = log ak
-4.1408
-1.7904 = log k
.2096 = log $\frac{1}{k}$
1.6203 = $\frac{1}{k}$
log .6203 =
-1.7926
2.9813
-4.8113

-1.7424
-1.8360
-1.9564

A = .9045   .0006473 = b

no 61

a Beauty worked up Aug 22.