Lab 6: Capacitors and Galvanometer

Graded

21 Hours, 27 Minutes Late

Student

Fady Youssef

Total Points

70.5 / 97 pts

Question 1

Part 1 Data Table

8 / 8 pts

✔ **– 0 pts** Correct

Question 2

Part 1 Plot

8 / 8 pts

✔ **– 0 pts** Correct

1 larger figure next time!

Question 3

Part 1 Two-Line Summaries

1 / 3 pts

– 0 pts Correct

– 2 pts Point adjustment

2 remember to only round error to the first digit! -1

3 use AE, not SE! -1

Question 4

Part 2 Data Table

8 / 8 pts

✔ **– 0 pts** Correct

Question 5

Hand calulations...

18 / 20 pts

✔ **– 0 pts** Correct

– 2 pts Point adjustment

4 1/Ceq, need to flip again -2

5 You must not have connected your circuit properly. This cannot be a correct experimental value.

Question 6

Questions

6.5 / 10 pts

− 0 pts Correct

− 3.5 pts Point adjustment

6 Here's Fink's solution:
Yes, you would expect to find the same regression coefficients in Step 3.1.2. This is because the proportionality constant in Q=kN is specific to each galvanometer—that is, the relationship between deflection and charge is determined by how the galvanometer is calibrated, not by the capacitor supplying the charge.
-2

7 specifically 1/4 a deflection -1

8 Using the water analogy, like there is a pipe connecting each of the buckets so that the water leaving one, enters another. Dr Finks sol: On the other hand, when they are connected in series, the power supply provides some charge to the first one, and this charge cascades so that all the following capacitors get the same charge "for free." So for a given potential difference, less charge is needed for a group of capacitors in series than for any one capacitor by itself. -0.5

Question 7

Error discussion

14 / 15 pts

− 0 pts Correct

− 1 pt Point adjustment

9 units? -1

10 Yes, you simply did not hook up the circuit properly.

Question 8

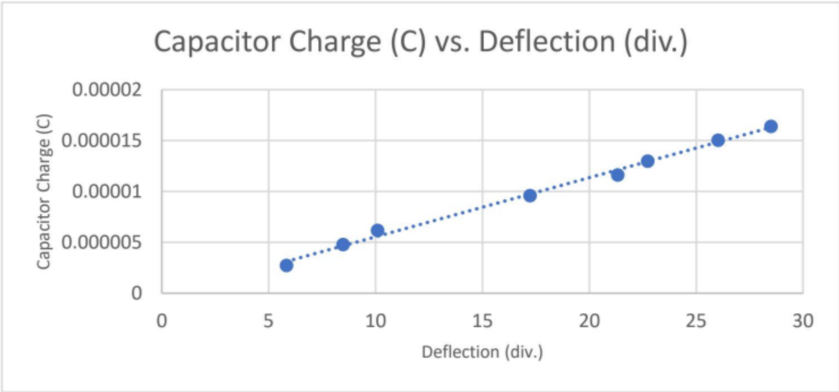
Challenge

7 / 25 pts

− 0 pts Correct

− 18 pts Point adjustment

Questions assigned to the following page: 1, 2, and 3



9.31899E-06

	Mean	SE	AE
Slope (C/div.)	5.81395E-07	-2.71547E-07	-5.32233E-07
Y-Intercept (C)	1.66647E-08	3.20839E-07	6.28845E-07

Slope (C/ div.):
Result: 5.8*10^(-7) +/- -2.7*10^(-7)
Range:3.1*10^(-7) to 8.5*10^(-7)

Y-int (C):
Result:1.67*10^(-8) +/- 3.21*10^(-7)
Range: -3.043 *10^(-7) to 3.377 *10^(-7)

Part A - Calibration of the galvanometer

Trial	Voltage	Def. right	Def. right	Def. left	Def. left
units	(V)	(div.)	(div.)	(div.)	(div.)
1	4	5.7	5.9	5.6	6
2	9.06	11.2	10.3	10.4	9.8
3	14.05	17.4	16.7	17.6	17.2
4	19.01	23.3	23.1	21.8	22.7
5	24.02	28.5	28.8	28.2	28.5
6	7.01	8.7	9.2	8.2	7.8
7	17	22.2	21.8	21.5	19.8
8	22.02	25.5	26.6	25.8	26.2

Avg. Def.	Charge
(div.)	(C)
5.833333	2.7E-06
10.1	6.2E-06
17.225	9.6E-06
22.725	1.3E-05
28.5	1.6E-05
8.475	4.8E-06
21.325	1.2E-05
26.025	1.5E-05

Question assigned to the following page: 4

Part B - Determining Capacitance

Unknown	Voltage	Def. right	Def. right	Def. left	Def. left
units	(V)	(div.)	(div.)	(div.)	(div.)
C_1	6.01	11.8	12.3	12.1	12.4
C_2	15.4	14.2	14.8	13.7	14.4
C_3	18.31	14.2	13.5	11.7	12.4
Parallel	10.99	14.4	13.5	13.8	14.7
Combo	9.7	12.3	11.8	13.2	11.6
Series	17.63	17.2	16.8	15.2	13.8

Avg. Def.	Charge	Capacitance
(div.)	(C)	(F)
12.15	7.1E-06	1.17814E-06
14.275	8.3E-06	5.40006E-07
12.95	7.5E-06	4.1211E-07
14.1	8.2E-06	7.47438E-07
12.225	7.1E-06	7.34456E-07
15.75	9.2E-06	5.20343E-07

No questions assigned to the following page.

No questions assigned to the following page.

Question assigned to the following page: 6

Questions:

1. If I used a known capacitor with a different capacitance and repeated the experiment, I would not expect the same regression coefficients in Step 3.1.2. Since the charge is given by $Q = CV$, a different capacitance would store an other charge for the same voltage. The galvanometer deflection N is proportional to charge, expressed as $N = kQ = kCV$, meaning the regression equation $Q = N/k$ has a slope of $1/k$. Since k depends on the capacitance used for calibration, a different capacitor would alter k and change the slope of the regression line. At the same time, the intercept might remain the same if no systematic errors are present.

2. If I had only used the forward polarity during calibration, it could introduce a systematic error due to an unaccounted offset in the galvanometer. Ideally, the galvanometer should have equal deflection in both directions for the same charge. However, if there is any asymmetry in the needle movement or zeroing, using only one direction could lead to an incorrect calibration constant k. This would affect the accuracy of charge calculations, leading to either an overestimation or underestimation of capacitance. The error would be systematic rather than random because it would consistently skew all measurements in the same direction.

3. Connecting capacitors in parallel increases the total capacitance because each capacitor provides an extra path for storing charge, similar to adding more buckets to hold water. More capacitors mean more charge can be stored for the same voltage, so the total capacitance increases. On the other hand, connecting capacitors in series decreases the total capacitance because the charge on each capacitor must be the same, and the total voltage is divided across them. This setup effectively increases the distance between the plates, making it harder to store charge. As a result, the total capacitance in series is always smaller than the smallest individual capacitor.

Question assigned to the following page: 7

Error Discussion Worksheet:

1. Reading Errors:
    - Voltage Reading on Multimeter (+/- .01)
    - Tick value left and right (+/- .5)
    - Parallax error in deflection reading (+/- 0.5 ticks)

2. The most prominent sources of random error in this lab came from slight variations in galvanometer deflection readings and minor inconsistencies in voltage measurements. When recording deflections, slight hand movements and viewing angles could lead to small differences in readings (+/- 0.5 ticks), especially when estimating between marks. Additionally, fluctuations in the multimeter reading (+/- 0.01 V) due to minor electrical instability in the power supply introduced slight inconsistencies in voltage measurements. These small variations in recorded values likely led to minor deviations in calculated capacitance across multiple trials.

3. Based on the experimental results, there is evidence of systematic error because the measured capacitance values were consistently lower than expected. This suggests a calibration issue with the galvanometer or a small but consistent voltage drop in the circuit that led to an underestimating charge. Additionally, if the galvanometer had a slight offset or if the switch contacts introduced extra resistance, it could have affected the deflection readings in every trial. Since this error appeared in all measurements rather than fluctuating randomly, it indicates a consistent issue in the experiment setup rather than random variation.

4. The most likely source of systematic error came from incorrect wiring in the series and parallel capacitor setups, leading to consistently inaccurate capacitance measurements. In the series setup, the measured capacitance was much lower than expected, likely due to extra resistance in the circuit reducing charge flow. Since capacitance in series should always be less than the smallest capacitor used, any incorrect connections could have further decreased the measured value, making it seem like the capacitors held less charge than they did. In the parallel setup, the measured capacitance was also lower than expected, suggesting that not all capacitors were properly connected to store charge. If one or more capacitors were not fully included in the circuit, the total capacitance would be lower than predicted instead of increasing as it should. Since capacitance is calculated using C = Q/V, any wiring mistakes would have affected charge distribution, leading to consistent underestimations across all trials. Because this issue appeared in every measurement, it introduced a systematic error that made all results less accurate in the same way rather than randomly varying from trial to trial.

Question assigned to the following page: 5

Sample Calculations:

Parallel:

$$C_{eq} = C_1 + C_2 + C_3 + \dots$$

$$\Rightarrow .0000012 + .00000054 + .000000412$$

$$\Rightarrow .00000213\,F$$

Percent error:

$$\left| \frac{.00000075F - .00000213F}{.00000213F} \right| \cdot 100 \approx 64.91\%$$

Series:

$$C_{eq} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

$$\Rightarrow \frac{1}{.0000012} + \frac{1}{.00000054} + \frac{1}{.000000412} = 5.11 \cdot 10^6\,F$$

$$\left| \frac{.00000052\,F - .000000195\,F}{.00000213F} \right| \cdot 100 \approx 166.79\%$$

Combination:

$$C_{eq} = \frac{1}{C_1} + \frac{1}{C_2} + C_3$$

$$\Rightarrow \frac{1}{.0000012} + \frac{1}{.00000054} + .000000412 \approx 2.7 \cdot 10^6\,F$$

$$\left| \frac{.000000734\,F - .000000782}{.000000782} \right| \cdot 100 \approx 6.13\%$$

Question assigned to the following page: 8

Challenge:

Specified Deflection: 16 ticks

Predicted Voltage: 17 V

Actual Deflection: 12 ticks

Points : 7