ILLINOIS INSTITUTE OF TECHNOLOGY - PHYS 221 L03

Lab Report - Lab 04: Capacitors

September 30, 2020

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Lab 04
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Lab 04: Capacitors

Part 1 Questions

1. Using the Capacimeter, measure the capacitance of each of the three capacitors given.
   Table 1:

Blue Capacitor	8.0 nF
Yellow Capacitor	21.9 nF
Disk Capacitor	35.6 nF

2. Connect them in series using the breadboards which have connectivity between all sets of five holes (at a minimum). Measure the effective capacitance of this combination. Repeat this for a parallel configuration. Which configuration produces a higher capacitance? Compare the measured values with those calculated from Equations 2 and 3.
   Table 2:

Series Capacitance	5.0 nF
Parallel Capacitance	65.7333333333333 nF

   Calculated:
   $C_{series} = ((1/C_1) + (1/C_2) + (1/C_3))^{-1} = 1/8 + 1/21.9 + 1/35.6 = 5.031$ nF
   $C_{parallel} = C_1 + C_2 + C_3 = 8.0 + 21.9 + 35.6 = 65.5$ nF

   % error = |experimental - actual| / actual x 100
   Using the % error formula, we can now compare the values of the calculated and the actual. Series capacitance values had a % error of 0.62%, while the parallel capacitance values had a % error of 0.355%. The values had a small margin of error, so it is safe to infer that the data is reliable.
   Overall, the parallel circuit configuration produces the higher capacitance.

Questions

1. Calculate the capacitance using Equation 1 for the various separation distances of task 1 (for part 2a). How do these values compare with the data taken with the capacimeter? Don't forget to take into account the dielectric constant for air.
   a. Table 3:

Material	k	d (m)	Number of Sheets	C (measured) nF	C (calculated) nF	Error (%)
Air	1.00059	0.01	0	31.96667	27.82	12.9734226
Air	1.00059	0.03	0	12.0	9.27	22.72361442
Air	1.00059	0.05	0	8.2	5.56	32.42226982

Air	1.00059	0.07	0	6.533333	3.97	39.170189
Air	1.00059	0.09	0	5.466666	3.09	43.45629634
Air	1.00059	0.12	0	4.5	2.32	48.48240961

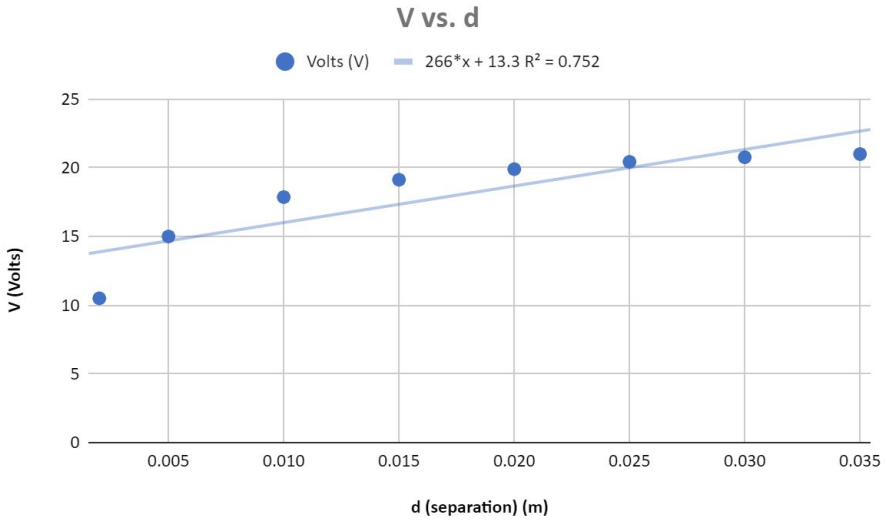
The % error between the measured and calculated capacitance values had some significant percentages. One explanation for this could be due to the temperature and humidity of the air.

2. Calculate the dielectric constant for the paper used. How do your values compare with the listed value from the table above?
    a. Table 4:

C w/ air (pF)	C w/ paper (pF)	calculated K	actual K	% error
31.966667	37.166667	1.163	1.5	22.4666667

Using the equation $KC_0 = C$ (2), where C_0 is the capacitance with the air while C is the capacitance with the paper, we solve for K, which equals 1.163. Choosing the lower range of the actual K, we discover the % error to be 22.466667%. K is below the range of what the K value should be for a piece of paper.

3. Calculate the dielectric constant for the transparency sheets. Does the capacitance of the parallel plates depend on the thickness of the dielectric?
    a. Using equation 2 from the previous question with the same values except the final capacitance is C = 33.53333, the value of K = 1.049. The capacitance of the parallel plates does depend on the thickness of the dielectric.
4. Show that the capacitance for the setup in Figure 4 is given by $C = (2E_0A/d) \times (\kappa1\kappa2/(\kappa1 + \kappa2))$ (4).
    a. Similarly to figure 1, a capacitor filled with two different dielectrics is equivalent to 2 capacitors in series with 2 different dielectrics.
    $1/C = 1/C_1 + 1/C_2$
5. Compare your experimental results of task 4 with Equation 4.
    a. For task 4, K is about equal to 1 because we did not use any dielectric in the capacitor. So then the equation becomes $C = E_0A/d = Q/V$, where Q was constant due to the fact that the plates were charged before d was changed. Therefore, since Q is constant, then V must increase as separation increases.
6. The dielectrics you insert between the parallel plates may have excess charge. What happens when you charge the plates, if this turns out to be true?
    a. It causes polarization of the charge inside, which therefore causes the overall voltage between the plates to decrease and capacitance to increase.
7. For Part 2b, create a plot of V vs d. What does the slope represent?
    a. Graph 1:



b.

The slope represents the magnitude of the electric field between the plates.

8. How much charge is found on the plates in Part 2b?
   a. Table 5:

Separation (m)	Volts (V)	C (F)	Q (C)
0.005	15	5.56E-11	8.34E-10
0.01	17.866667	2.78E-11	4.97E-10
0.015	19.133333	1.85E-11	3.55E-10
0.02	19.9	1.39E-11	2.77E-10
0.025	20.433333	1.11E-11	2.27E-10
0.03	20.766667	9.27E-12	1.92E-10
0.035	21	7.94E-12	1.67E-10
0.002	10.5	1.39E-10	1.46E-09

$Q = CV = (E_0A/d) \times V$, so using the values from the data gathered we calculate the charge of the plates when at different separations and voltages.