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PHYS 102 EXPERIMENT 2: EQUIPITENTIALS AND RADIAL ELECTRIC FIELD LINES

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Data & Results: [20]

r converted to m in calculations

r (cm)	V (V)	E ($\frac{V}{m}$)	1/r ($\frac{1}{m}$)
2.5	0		
3.0	2.956		
3.5	6.135	592.4	28.6
4.0	8.81	515.6	25.0
4.5	11.29	443.3	22.2
5.0	13.26	375.3	20.0
5.5	15.14	395.2	18.2
6.0	17.09	298.3	16.7
6.5	18.22		
7.0	20.0		

Table 1: Electric potential and field of two concentric rings as a function of r

for $r=3.5 \Rightarrow E = \frac{1/3}{0.005}\left[\frac{1}{4}.0 - 2.(2.956) + 2.(8.81) - \frac{1}{4}.(11.29)\right] = 592.4\, V/m$

; so on

using meter

r (cm)	V [measured]	V [calculated]	% Error
4.0	8.81	9.13	3.50
4.5	11.29	11.42	1.14
5.0	13.26	13.46	1.49
5.5	15.14	15.32	1.18

% Error $\rightarrow \frac{|V_{exp} - V_{theo}|}{V_{theo}} \times 100$

Table 2: Equipotentials

for $r=4 \Rightarrow V(4) = 20 . \frac{\ln(4/2.5)}{\ln(7/2.5)} = 9.13$

r (cm)	V (V)	E ($\frac{V}{m}$)	1/r ($\frac{1}{m}$)
2.5	8.90		
3.0	9.78		
3.5	10.49	158.8	28.6
4.0	11.43	212.5	25.0
4.5	12.57	226.2	22.2
5.0	13.67	226.0	20.0
5.5	14.84	216.3	18.2
6.0	16.03	378.5	16.7
6.5	18.47		
7.0	20		

Table 3: Electric potential and field of dots as a function of r

for $r=3.5 \Rightarrow E = \frac{1/3}{0.005}\left[\frac{1}{4}.(8.90) - 2.(9.78) + 2.(11.43) - \frac{1}{4}.(12.57)\right] = 155.5$

; so on

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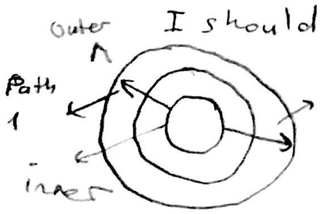
Questions:

1) [5] What would you expect for the variation of potential V with radius r for a different radial direction? Measure a few points to check out your prediction.

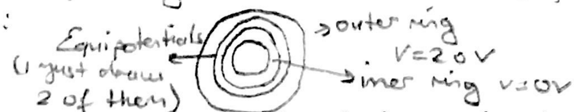
I expect that every point on the equipotentials should be the same and therefore, no matter which radial direction I choose I should be able to measure same volts That is path 1 and 2 does not matter:



Path 2 | However, in reality I could not measure same volt values on same equipotential lines, even on the inner radius where V=0, I measure V=0 on pin but some other measurements along equi. line is 0.120 V, 0.138 V so on. Thus for path 2, I get a lower voltage values in intermediate steps. This is because of both my measurement error and device (Voltmeter, board etc) errors.

2) [5] Based on your measurements of electrical potential, what must be the direction of the electric field? What do the equipotentials look like?

Electric field lines go from positive potential to ground. Therefore, their direction must be radially inward (outside to inside). Because of the symmetry of the system, equipotentials look like a bunch of rings where Electric field value constant along the ring That is:



3) [5] If the power supply voltage in the experiment were doubled, how would the field pattern change? How about the potentials?

2 $E = \frac{dV}{dr} = \frac{1/3}{\Delta r}\left[\frac{1}{4}V_{-2} - 2V_{-1} + 2V_1 - \frac{1}{4}V_2\right] \xrightarrow{V'=2V} \frac{1/3}{\Delta r}\left[\frac{1}{4}2V_{-2} - 2.2.V_{-1} + 2.2V_1 - \frac{1}{4}.2.V_2\right]$

$= 2E \Rightarrow$ if E doubled, Electric field lines are doubled, the density of the lines doubled.

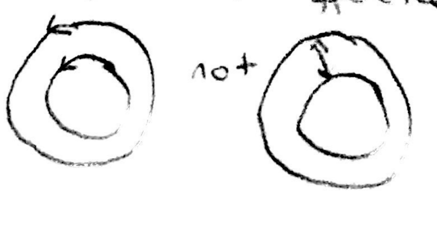
1 $V(r) = V_0 \frac{\ln(r/a)}{\ln(b/a)} = V \Rightarrow 2V_0 \frac{\ln(r/a)}{\ln(b/a)} = 2V$, thus potentials are doubled

Note: the last one should be top of the previous one.

4) [5] Why does not current flow along equipotential lines?

Since current flows in the direction of the electric field, and equipotential lines are at everywhere perpendicular to that direction, no current flows along equipotential lines. Another explanation, since the voltage is same along equipotential lines, current cannot flow due to lack of potential difference.

Note: According to TA question asks



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Conclusion: [15] This experiment was aimed to introduce the electric field concept using electric field and equipotential lines for both two oppositely charged concentric rings and two oppositely charged dot configurations. The experiment allows us to inspect them in two ways: experimentally and theoretically. Experimentally, we saw that voltages are much or less the same on equal distances from the inner circle which proves that equipotential lines are real and voltage differences increase linearly as we go from inner to outer rings. Theoretical part uses two equations: $\frac{dV}{dr} = \frac{1/3}{\Delta r}\left[\frac{1}{4}V_{-2} - 2V_{-1} + 2V_{1} - \frac{1}{4}V_{2}\right]$ for calculating Electric Field and $V(r) = V_0 \frac{\ln(r/a)}{\ln(b/a)}$ for calculating V theoretical. It turns out that V theoretical is so close to the measured V for middle values ($r = 4$ to 5.5 cm) with average error of 2%. Using first equation we find Electric fields created by both rings and point charges for various r's. Then we inspect the relationship between E and $1/r$ by plotting their values and we get the opportunity to see that they are increase linearly. To sum up, I learned equipotential lines, 2 useful formulas for finding V and E from <u>experimental</u> values and E, $1/r$ relationship and also from questions we were asked I learned why current do not flow along equipotential lines, what would field pattern and potentials changed if power supply voltage were doubled, what equipotentials look like and the direction of the electric field, finally, how V change across different radial directions.

There were two types of errors in this experiment: first one is from the voltmeter. It's uncertainty was 0.001 for $V < 10V$ and 0.01 for $V > 10V$. Second one is mostly from me but also from carbon paper and metal pins. As small distances made a huge differences in voltages I may not exactly measure the r with 0.5 cm differences. It can be seen on table 2 that where the carbon paper explicitly show the point I should take as a radius my errors 1.14% and 1.18%, otherwise 3.50% and 1.49%. Another source of error is metal pin is not a point particle to put it in exactly on 2.5 cm away from center so that when I calculate error for $r = 3.0$, I found 22.2% error mostly because of I couldn't measure due to width of metal pin. Finally, the rings widths are not same in all places etc.

Questions to think about 1. a) yes b) No 2. No, otherwise two dif. V for same point is impossible I wrote too long, sorry :)

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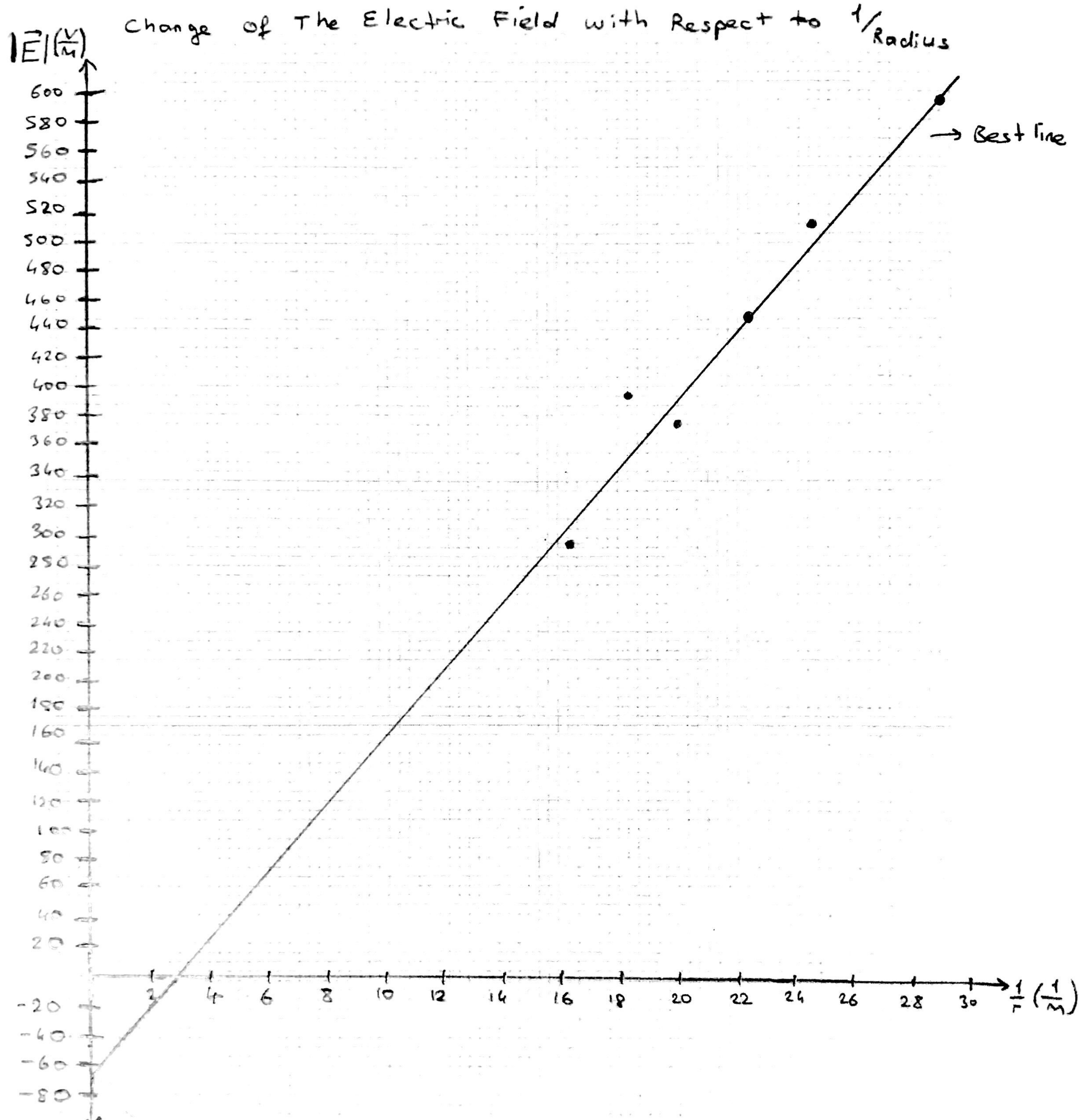
Plot [15]



y intercept = -65.68
x intercept = 2.85

$$M_{best} = \frac{592.4-0}{28.6-2.9} = 23.05$$