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ENGS124 Electricity and Magnetism Lab Section B

Investigating equipotential lines in electric fields

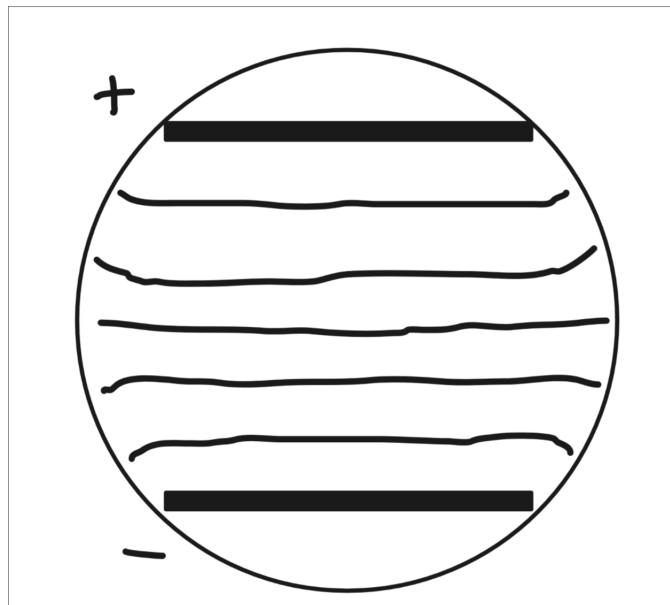
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1 Linear setup

We have two parallel plates creating a uniform electric field in the water. Therefore we have a linear relationship between distance and voltage.

$$V = \int_0^d E ds = Ed$$



A round plate was filled with water, two plates were connected to a 7V power supply, and the voltage was measured inside the circle going from the negative electrode to the positive. The spacing between the equipotential lines are approximately equal, with distortions in the corners.

Variable	Value	Resolution
Distance from negative electrode	Controlled	1mm
Voltage	Measured	0.01V

Table 1: List of variables

Instrument or material	Description
Voltmeter	A voltmeter
Lab bench power supply	With sufficient voltage range
Electrodes	Two plates and a thin rod
Cables	For the multimeter and power supply

Table 2: List of instruments and materials

Source of error	Type of error	Countermeasures
Inconsistent electrode angles	Random	It was difficult to maintain a perpendicular electrode to the surface of the water, which may change the voltage reading. Helping hands were used.
Water resistance	Random	The water used had a comparable resistance to the internal resistance of the multimeter, which may distort the results

Table 3: Estimated errors

d (cm)	V (V)	$E_x = -\frac{\Delta V}{\Delta d}$ (V/cm)
2.00	2.27	N/A
2.50	2.49	0.44
3.00	2.76	0.49
3.50	3.02	0.50
4.00	3.27	0.50
4.50	3.51	0.49
5.00	3.79	0.51
5.50	4.01	0.50
6.00	4.24	0.49

Table 4: Part 1 data

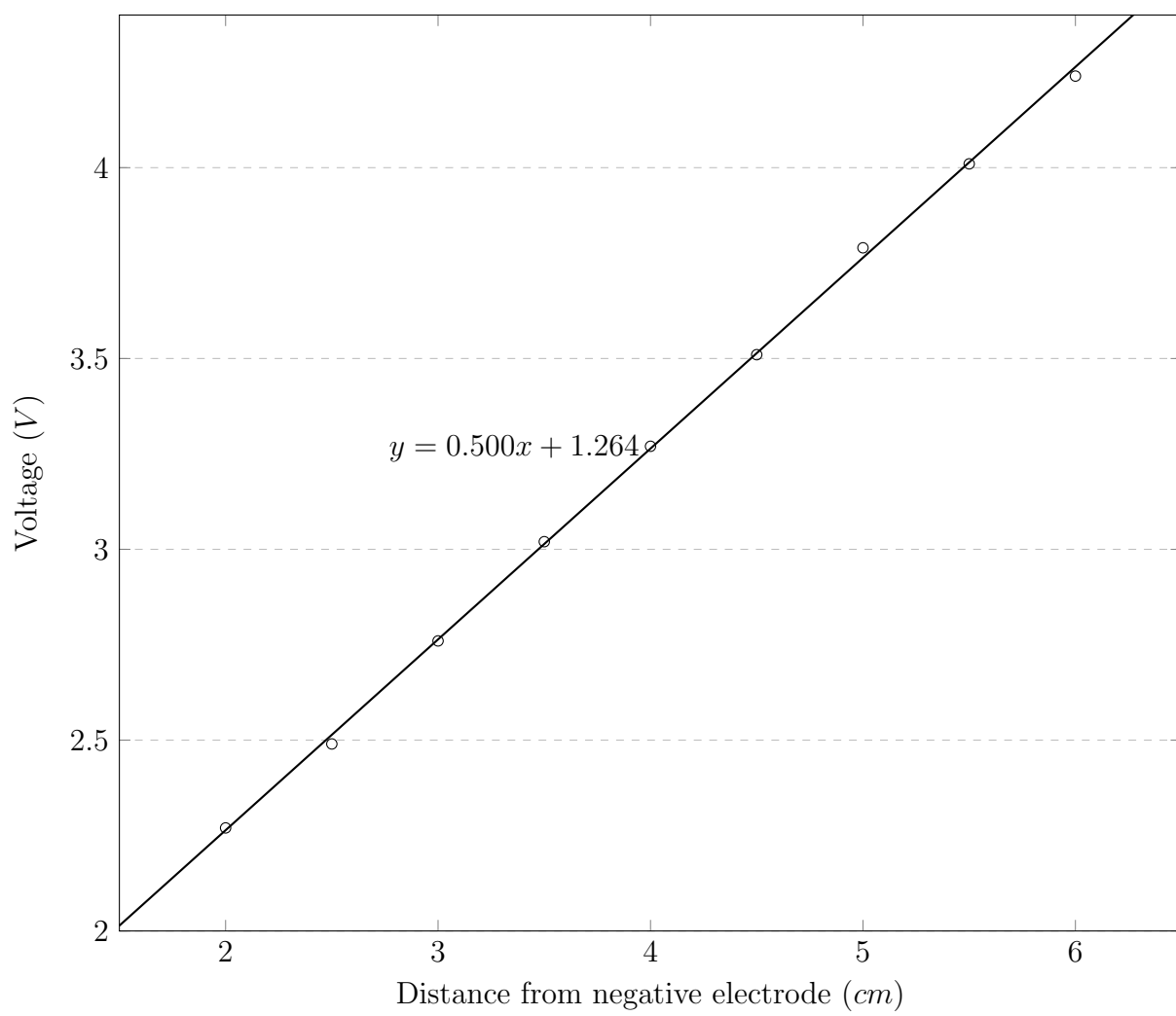


Figure 1: Plot of voltage and distance

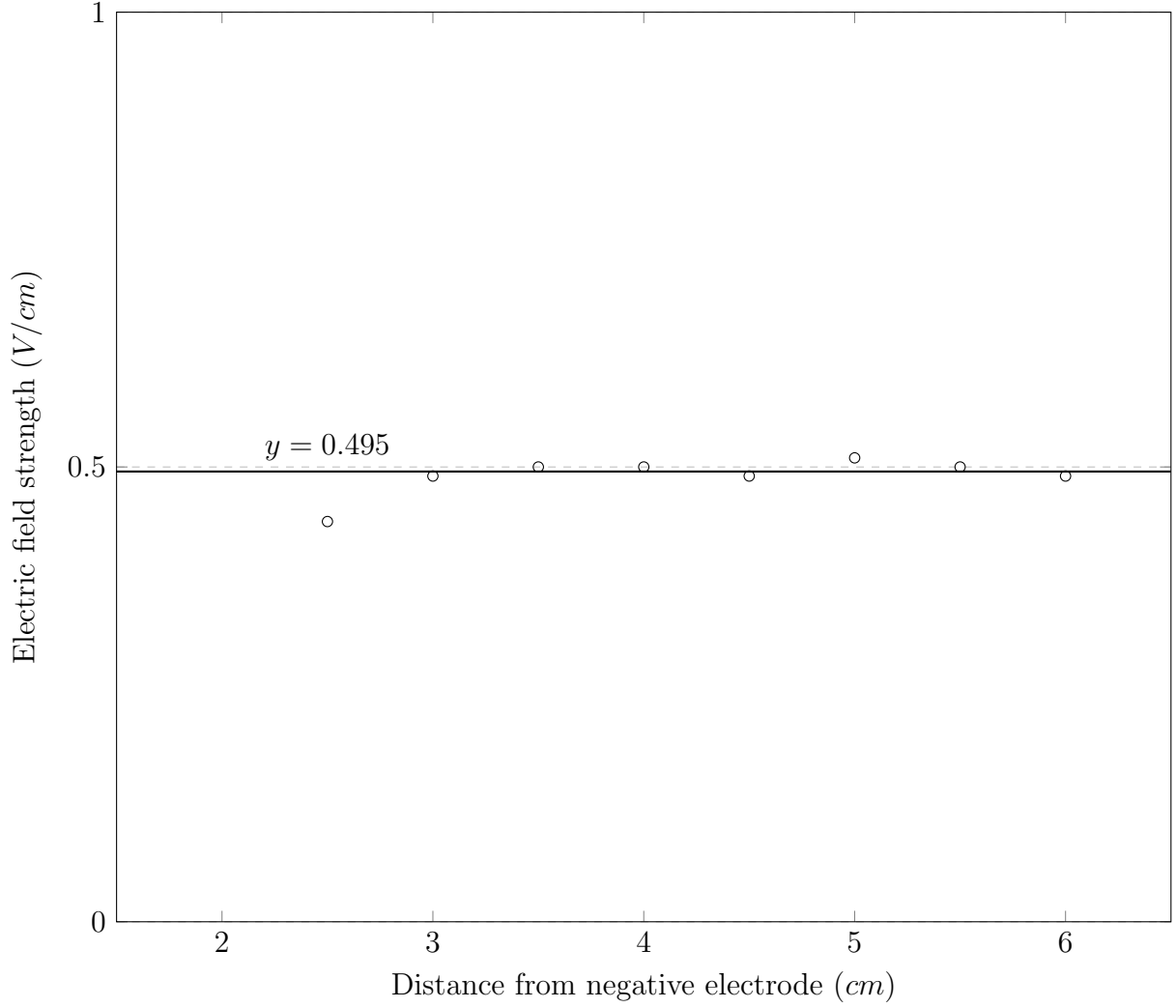


Figure 2: Plot of electric field strength and distance

We see that voltage is linearly dependant from distance, as the theory suggested. The electric field is constant along the axis. We have similar situation in a parallel plate capacitor, where the electric field is constant $E = \frac{\sigma}{\epsilon_0}$. As the size of the plates were comparable to the distance between them, we had a non-uniform field on the edges of the circle, as seen on the qualitative plot. This is because an electric field is constant in parallel plate capacitors, because the distance between the plates is significantly smaller than the size of the plates.

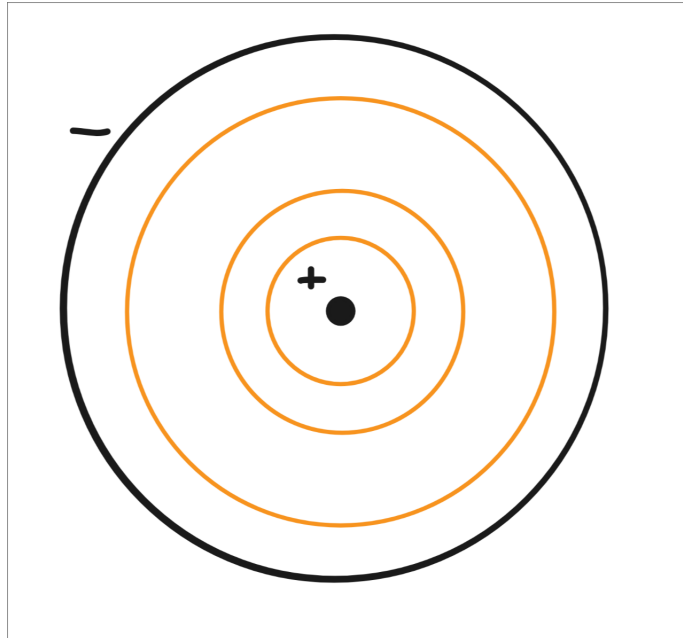
2 Concentric circle setup

We have a circular negative electrode on the outside and a thin positive electrode in the center of the circle. The electric field of a point charge is as follows:

$$E \sim \frac{1}{d} \text{ and } V \sim \ln(d)$$

We can use the Gauss law to prove the fact:

$$\Phi = E \cdot 2\pi \cdot d \cdot l = \frac{\lambda l}{\varepsilon_0} \implies E = \frac{\lambda}{2\pi\varepsilon_0 d} \implies V = \int_{d_0}^d \frac{\lambda}{2\pi\varepsilon_0 s} ds = \frac{\lambda}{2\pi\varepsilon_0} \ln\left(\frac{d}{d_0}\right)$$



A round plate was filled with water, an outer circular electrode was connected to ground and the inside rod electrode is connected to a 7V power supply. The voltage was measured going from the center to the perimeter of the circle. The spacing between the equipotential lines become larger the further we measure.

Variable	Value	Resolution
Distance from negative electrode	Controlled	1mm
Voltage	Measured	0.01V

Table 5: List of variables

Instrument or material	Description
Voltmeter	A voltmeter
Lab bench power supply	With sufficient voltage range
Electrodes	Long wall and a thin rod
Cables	For the multimeter and power supply

Table 6: List of instruments and materials

Source of error	Type of error	Countermeasures
Inconsistent electrode angles	Random	It was difficult to maintain a perpendicular electrode to the surface of the water, which may change the voltage reading. Helping hands were used.
Water resistance	Random	The water used had a comparable resistance to the internal resistance of the multimeter, which may distort the results
Center electrode position	Random	The position of the electrode in the center is not technically in the center.

Table 7: Estimated errors

d (cm)	V (V)	$E_x = -\frac{\Delta V}{\Delta d}$ (V/cm)	$\ln(d)$
1.00	4.46	N/A	0.00
1.50	3.84	1.24	0.41
2.00	3.45	0.78	0.69
2.50	3.11	0.68	0.92
3.00	2.86	0.50	1.10
3.50	2.60	0.52	1.25
4.00	2.43	0.34	1.39
4.50	2.33	0.20	1.50
5.00	2.18	0.30	1.61

Table 8: Part 2 data

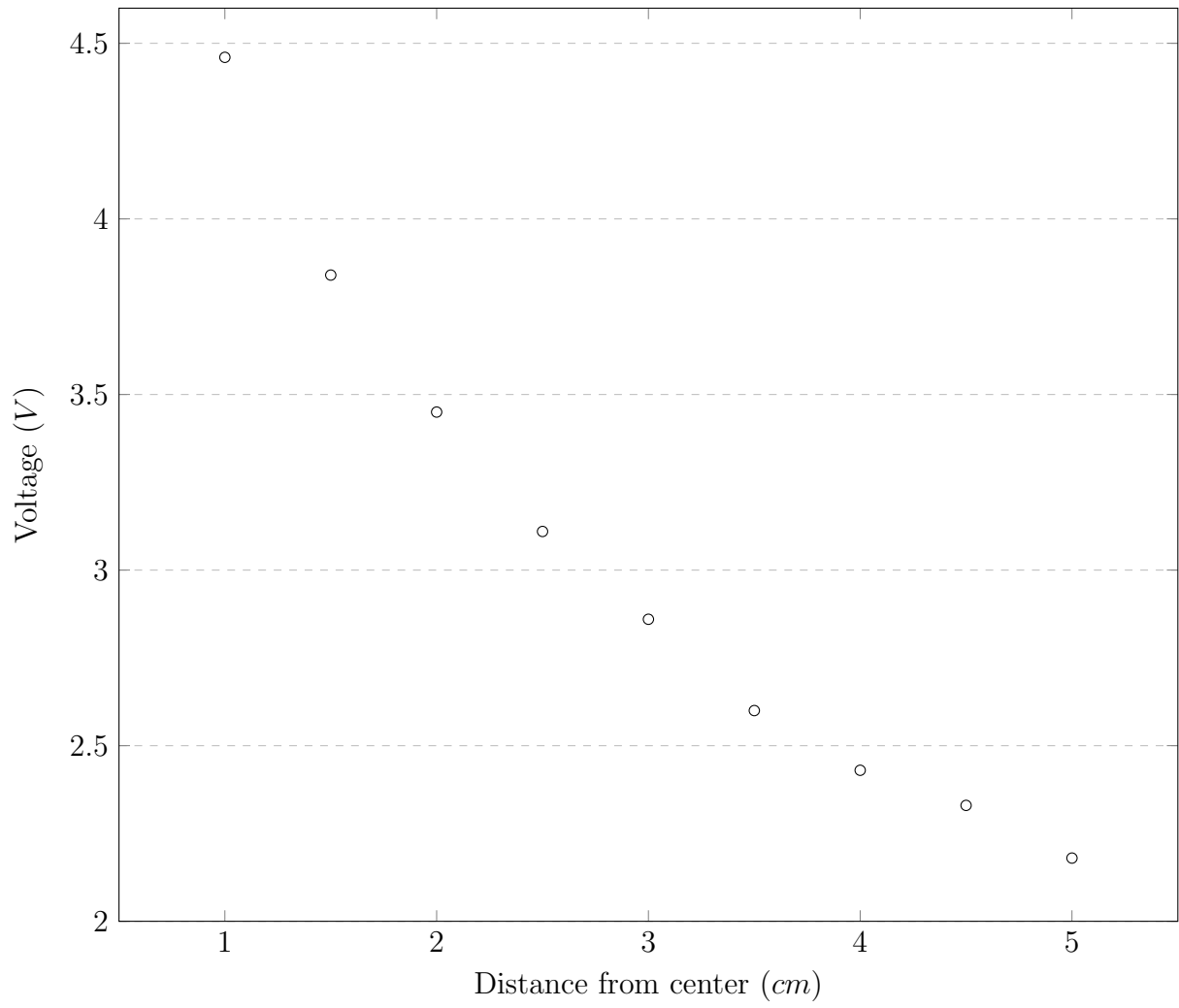


Figure 3: Plot of voltage and distance

The graph is similar to $y = -\ln(x)$, but we cannot be sure.

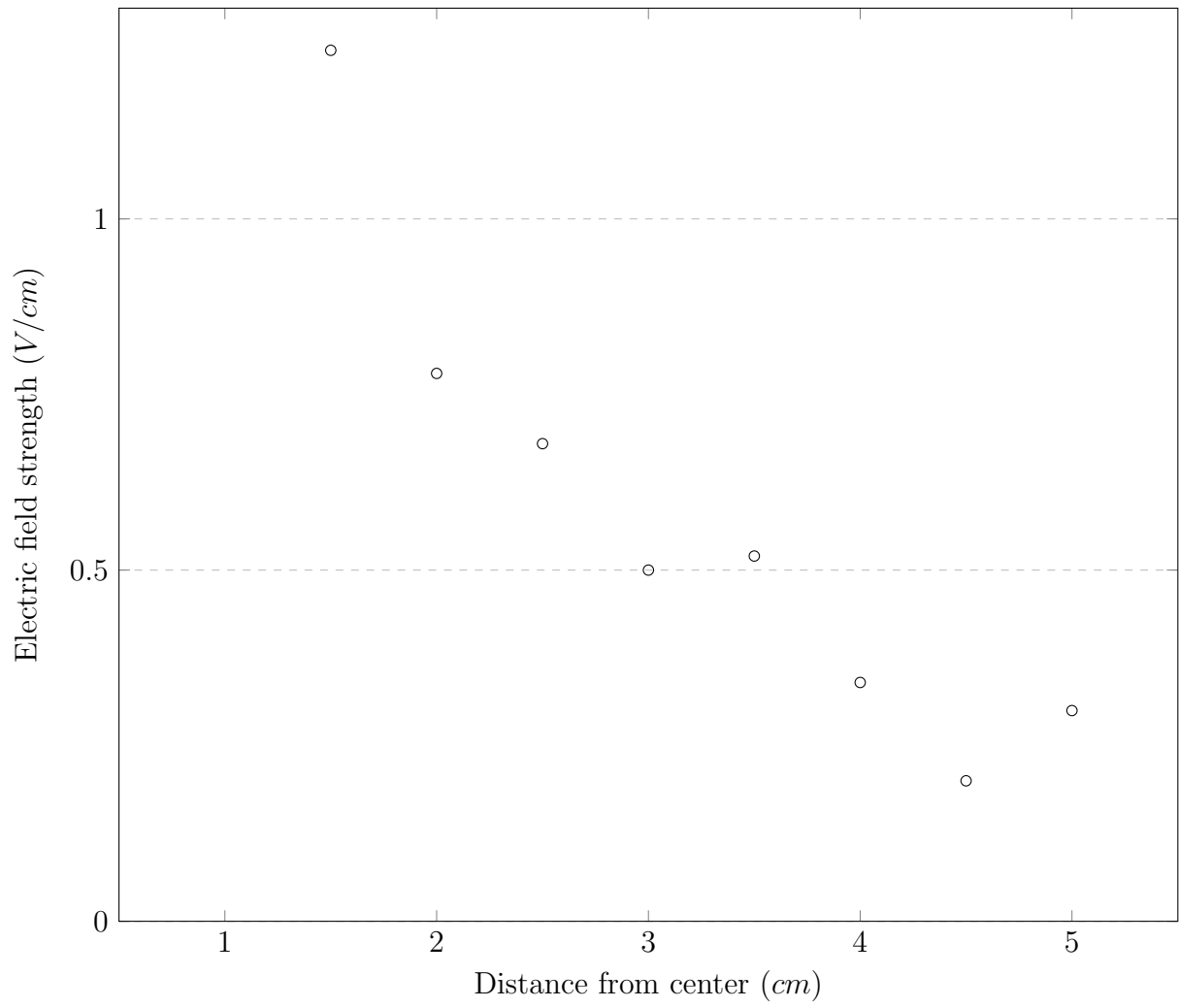


Figure 4: Plot of electric field strength and distance

The graph is similar to $y = \frac{1}{x}$, but we cannot be sure.

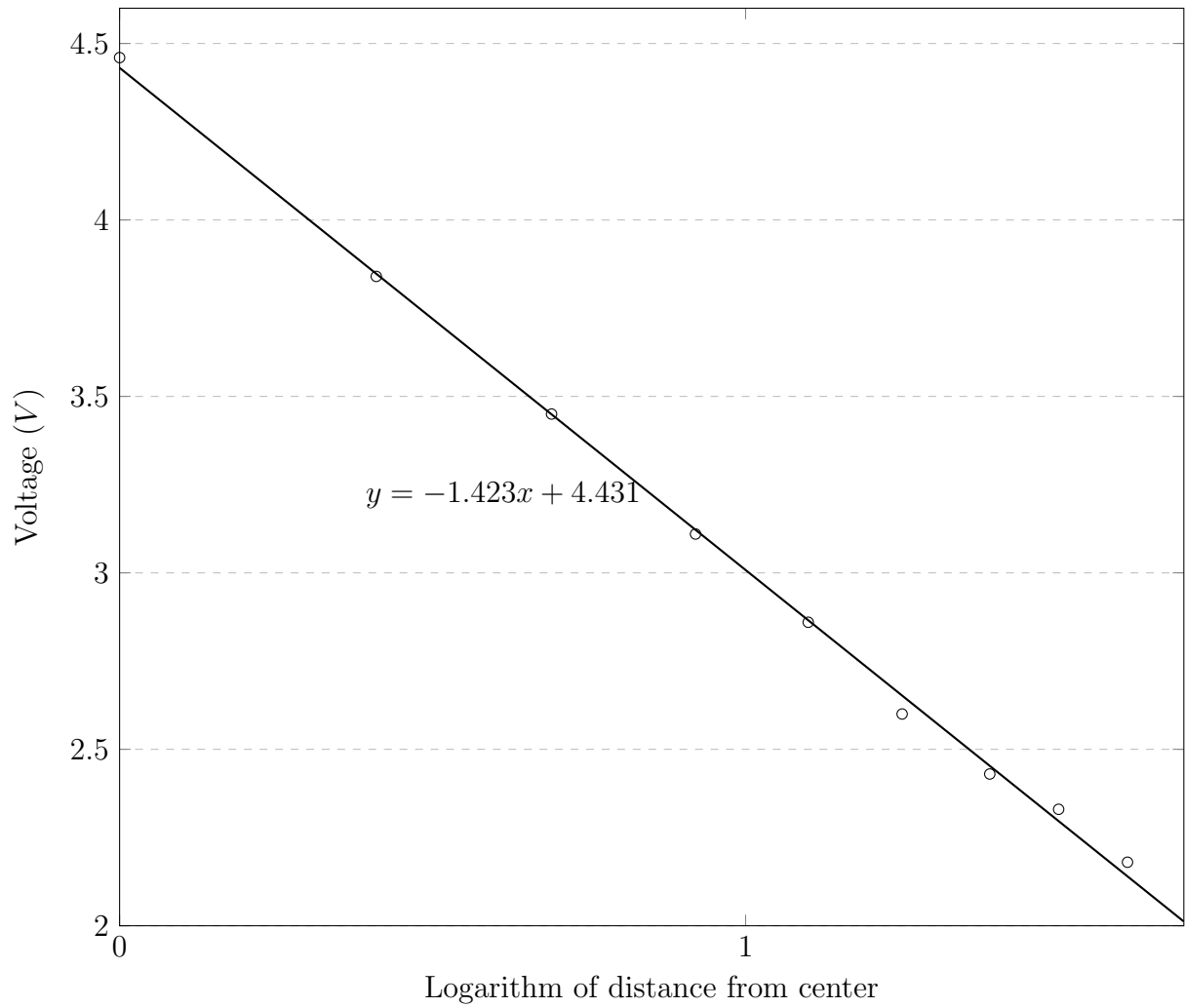


Figure 5: Plot of voltage and logarithm of distance

We have a similar case as with an infinitely long wire, where the electric field is inversely proportional to the distance from the center of the wire. We have a linear relation between voltage and the logarithm of distance, meaning that $V \sim \ln(d)$.