Lab 2: Coulomb's Law

Jonah Spector, Alec Gray, Nathan Rettig

February 6, 2025

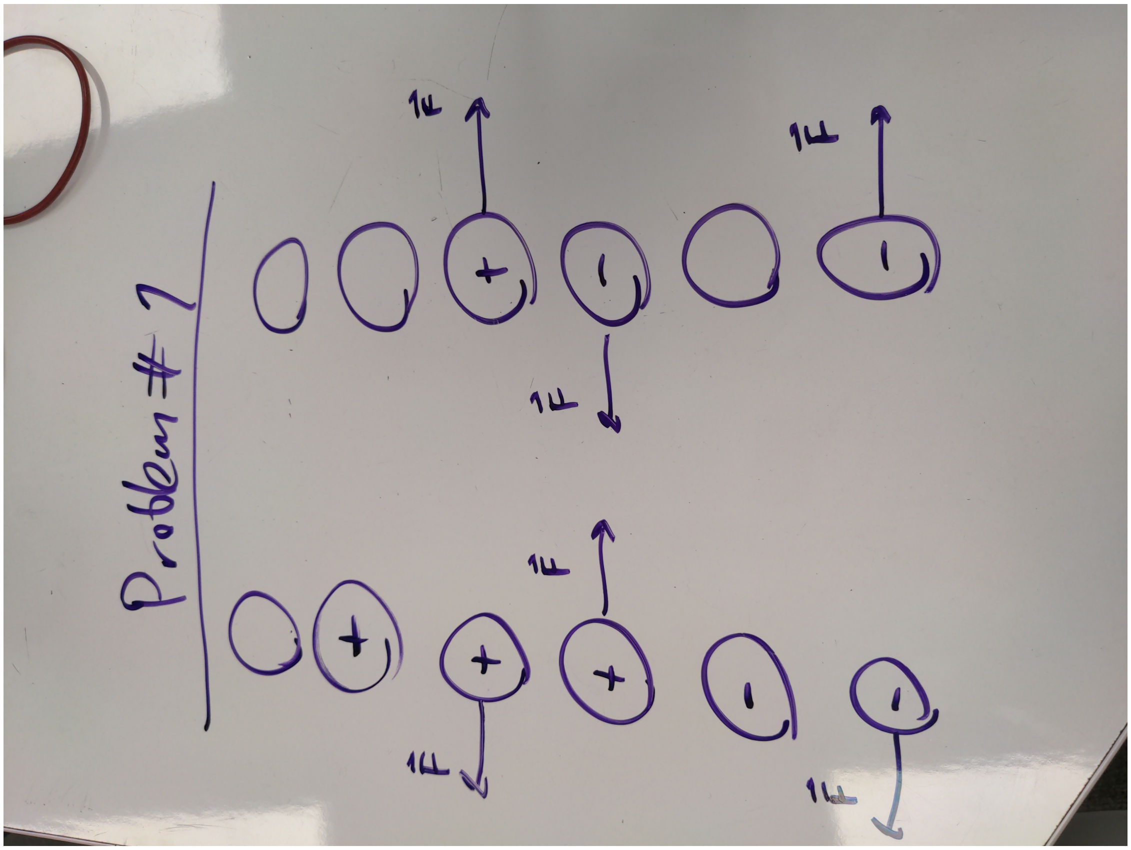
1 Introduction

In this lab, we explore the effects of Coulomb's law, which models the force generated between two charged particles. We will look at how similar charges affect each other, specifically how the force applied to each is impacted by the distance between the two. Understanding this law can help in predicting the interactions between electronic devices emitting EM fields, which may interfere with one another's functions if brought too close, such as bringing a magnet too close to a laptop screen.

Materials: High voltage power supply, Coulomb balance, marker.

2 Problem 1

Procedure: Draw out a list of each combination of charges, being either positive, negative or neutral. Apply each charge to the spheres and bring them close, take note of the forces applied. Ground each sphere and move to the next combination. Repeat until each combination has been tested.



3 Problem 2

Procedure: Slowly bring the voltage up to 6kV. Ground each of the spheres. Charge up each sphere to 6kV. Slowly bring them closer together. Observe what happens. Repeat the process with one sphere at 6kV and one at 1kV.

Results: When the spheres are far away from each other, they don't affect each other. When brought close to each other, they repelled. When they were both charged to 6kV, they had a higher angle than with the 1kV and 6kV. The spheres start to repel more as they get closer to each other. There was no visible movement when they were as far away from each other.

Analysis: This means that the forces between them are proportional to their distance from each other. Also, this says that the higher the difference in potential, the higher the forces on them. They could repel each other because they are the same charge and the same charges repel each other.

4 Problem 3

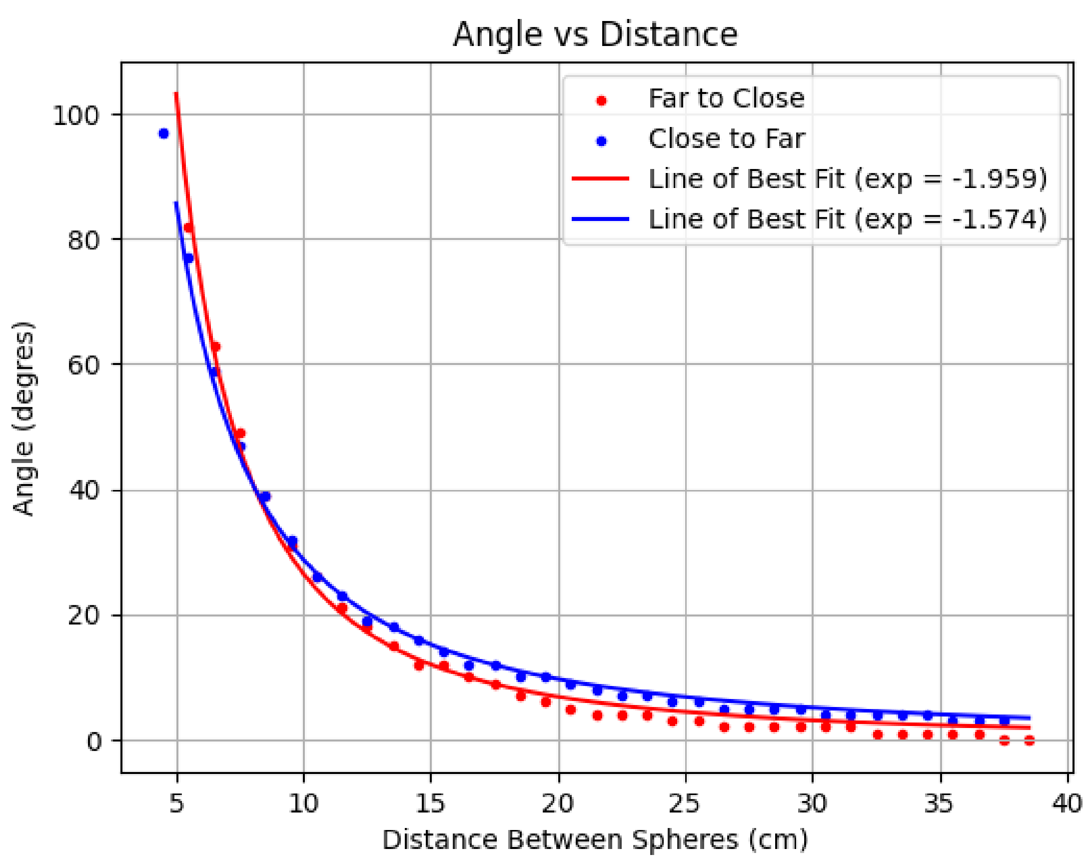
Procedure: Ground both of the spheres. Bring the power supply up to 6kV slowly. Charge each sphere by touching the hot wire to each. Slowly bring the spheres together and measure the distance and angle every centimeter. Continue until you reach 0 cm away from each other. Repeat these steps but start with the spheres close and bring them away.

Data:

Dist.	Ang. 1	Ang. 2	Dist.	Ang. 1	Ang. 2
0	97	-	...	...	...
1	77	82	18	7	4
2	59	63	19	7	4
3	47	49	20	6	3
4	39	39	21	6	3
5	32	31	22	5	2
6	26	26	23	5	2
7	23	21	24	5	2
8	19	18	25	5	2
9	18	15	26	4	2
10	16	12	27	4	2
11	14	12	28	4	1
12	12	10	29	4	1
13	12	9	30	4	1
14	10	7	31	3	1
15	10	6	32	3	1
16	9	5	33	3	0
17	8	4	34	-	0

[1]:
```
from math import *

import matplotlib.pyplot as plt
import numpy as np
from scipy.optimize import curve_fit

# Distances (cm)
dist_1 = np.arange(34, 0, -1)
dist_2 = np.arange(0, 34, 1)

# To account for the measurement distance not being between the centers of the
↪spheres
adjust = 4.5 # cm

dist_1 = dist_1 + adjust
dist_2 = dist_2 + adjust

comp_dist = np.linspace(5, 34+adjust, 100)
comp = lambda x: (1 / (4 * pi * 8.8541 * (10**-12))) * 2 * charge / x**2

# Trial angle data (1: far to close, 2: close to far) (angle)
angle_1 = np.array([0, 0, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 3, 3, 4, 4, 4, 5, 6,
↪7, 9, 10, 12, 12, 15, 18, 21, 26, 31, 39, 49, 63, 82])
angle_2 = np.array([97, 77, 59, 47, 39, 32, 26, 23, 19, 18, 16, 14, 12, 12, 10,
↪10, 9,8, 7, 7, 6, 6, 5, 5, 5, 5, 4, 4, 4, 4, 4, 3, 3, 3])
```

```python
def func(x, r, a):
    return a * x**r

popt1, pcov2 = curve_fit(func, dist_1, angle_1)
popt2, pcov2 = curve_fit(func, dist_2, angle_2)

# Plotting, display exponential of line of best fit
plt.scatter(dist_1, angle_1, marker=".", c="red")
plt.scatter(dist_2, angle_2, marker=".", c="blue")
plt.plot(comp_dist, func(comp_dist, popt1[0], popt1[1]), c="red")
plt.plot(comp_dist, func(comp_dist, popt2[0], popt2[1]), c="blue")
plt.title("Angle vs Distance")
plt.xlabel("Distance Between Spheres (cm)")
plt.ylabel("Angle (degres)")
plt.legend(["Far to Close", "Close to Far", f"Line of Best Fit (exp = 
 ↪{round(popt1[0], 3)})", f"Line of Best Fit (exp = {round(popt2[0], 3)})"])
plt.grid()
```



Analysis: The line of best fit's proportionality for the first trial, which went from far away to close, is very close to -2 at a value of -1.959. The second line of best fit is less accurate, but the second trial, which went from close to far away, was preformed immediately after the first trial without the angle being re-zeroed beforehand.

It is also important to mentioned that an adjustment of +4.5 cm was added to the distance reading measurements. This accounts for 0 cm actually representing contact between the spheres instead of the distance between their centers. (Gauss' law proves that a uniformly charged sphere acts like a point charge to test charges outside the sphere). Each sphere had a radius of around 2.25 cm, so both together yield 4.5 cm.

5 Conclusion

After observing the effects that charged objects have on each other, we can see the importance of Coulomb's law. We found that when the spheres were closer to each other, they had a higher force applied; when they were further, they had less force applied. Our experimental value for the proportionality of distance to force was -1.959, which was very close to the actual value of -2.