COULOMB'S LAW

Purpose: To investigate how the electrostatic force between charged objects depends on their separation.

Equipment:
2 copper spheres with stands
meter stick with stand
lab jack with thin wood platform
force scale
hair drier
black plastic rod
white fur
lab stand
caliper

Theory: Fig. 1 shows two charges, Q_1 and Q_2, separated by distance d.

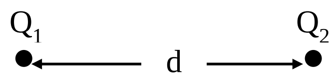

Figure 1

The magnitude of the electrostatic force between Q_1 and Q_2 is given by Coulomb's Law:

$$F = k\frac{Q_1 Q_2}{d^2}$$

where $k = 9 \cdot 10^9 \frac{N \cdot m^2}{C^2}$.

When the two charges are equal, $Q_1 = Q_2 \equiv Q$, we can write: $F = k\frac{Q^2}{d^2}$.

Procedure:

The experimental apparatus is shown in Fig. 2.

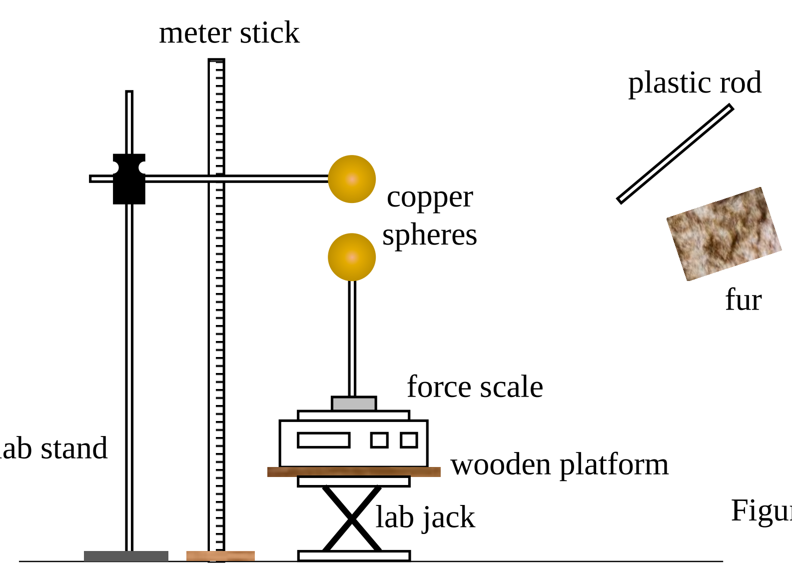

Figure 2

1. Place the meter stick vertically in the wooden stand, so that larger numbers are at the bottom.

2. Use the caliper to measure diameter D of one of the spheres. Record it in the *Data* section.

3. With the upper sphere out of the way, place the lower sphere on the scale. Change the units to

measure the force in newtons (N, not GN!)). Zero the scale so it shows 0 N.

4. Raise the lab jack to its highest position. The lab jack tends to change its tilt when the direction of travel is reversed. Therefore, you should lower the jack by about ten turns, until the wooden platform is at the height that corresponds to a "nice" number on the meter stick (for example 80 cm, as opposed to 79.6 cm). This will be the initial height of the platform, h_0, which you should record in the *Data* section.

5. Place the upper sphere on the lab stand, making sure that it is aligned directly above and barely TOUCHING the lower sphere (the reading on the scale should be close to zero).

6. Using the plastic rod and fur, take turn charging both spheres. Note: to efficiently transfer charge, it is necessary to "vigorously" rub the rod with the fur and then "smear" different parts of the rod over the sphere. Get as much charge on the spheres as possible.

Important: Do the following relatively quickly to minimize charge leakage from the spheres. If the air is humid, use the hair drier to dry the air around the spheres.

7. Charge both spheres so that the scale reads the highest force possible and is stable.

8. Now, quickly allow the spheres to make contact by slightly increasing the platform height. Because the spheres are conductors, the charges will quickly redistribute themselves so that the same amount of charge (Q) will exist on each sphere.

9. In Table 1, record the values of height h (make it a round number) and force F when the spheres are barely touching.

10. Lower the platform by 1.0 cm and record height h and the force value F on the scale. Continue lowering the platform in increments of 1.0 cm and record F and h until the force value either reads zero or remains constant.

11. Calculate the center-to-center separation (d) of the spheres by noting that $d = h - h_0 + D$. This is illustrated in Fig. 3. Record d in Table 1.

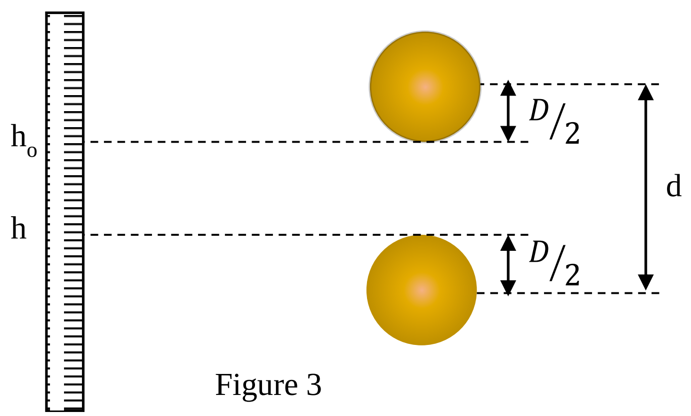

Figure 3

12. Discharge the spheres by touching them with a metal, non-grounded object (e.g. a key). Repeat the experiment two times and record in Table 2 and Table 3.

Data:

Diameter of the sphere, D = ________ m   Initial height, h_0 = ________ m

Table 1 - Trial 1

h (m)	d (m)	Force (N)

Table 2 - Trial 2

h (m)	d (m)	Force (N)

Table 3 - Trial 3

h (m)	d (m)	Force (N)

Analysis:

1. For each trial, enter the values for d and F into Excel and plot the data.

2. Fit the data to a power function $y = A \cdot d^{-B}$ (not polynomial!) and display the equation on the graph. Write the results of your fit in Table 4 below:

Table 4

	A	B
Trial 1		
Trial 2		
Trial 3		

3. Does your coefficient B agree with Coulomb's Law: $\mathrm{F} = \mathrm{k}\frac{\mathrm{Q}^2}{\mathrm{d}^2} = k\mathrm{Q}^2\mathrm{d}^{-2}$? What value would you expect B to have?

   ____

   If your results do not agree with Coulomb's Law, suggest possible reasons for the discrepancy:

   ____

   ____

4. Delete the first two points from your Excel file. Does the fit improve? Is it closer to Coulomb's Law? Explain.

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Record the new values of A and B in Table 5.

Table 5

	A (without the first two points)	B (without the first two points)
Trial 1		
Trial 2		
Trial 3		

5. Using Coulomb's Law and your fit values for A and B from Table 5, calculate Q for each trial and record in Table 5.

Table 5

	Q
Trial 1	
Trial 2	
Trial 3	
Average	

6. For the three values of Q, find the standard deviation δQ:

$$\delta Q = \_\_\_\_\_\_\_\_\_\_$$

$Q_{avg} \pm Q$ = (________ ± ________) (C)

7. For the three values of B, find the standard deviation δB:

$$\delta B = \_\_\_\_\_\_\_\_\_\_\_\_$$

$B_{avg} \pm \delta B$ = (___±______)

Discussion & Conclusions

Based on Q_{avg}, approximately what voltage are you charging a single sphere? Note: for a single sphere, $V = k \cdot Q/R$, where R is the radius of the sphere.

V = _______________ (V)

If you touch a 110 V electric outlet it can kill you. How come you don't get seriously injured when you touch the sphere in this experiment?

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