Electrostatics

PreLab submission with a pass grade is required to begin the lab.
Must be submitted no later than a day before the lab.

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Readings

Electric Charges & Coulomb's Law, A Short Review

By observing the attractive and repulsive forces between certain objects, we could conclude that there is not one, but two types of charge that can explain all the interactions. If you charge two same objects the same way, they repel, which means like charges repel.

By introducing the law of conservation of charge later on, we started calling one charge positive and the other negative. Namely we understood that charge exchanges between the objects, when certain objects touch, like fur and a piece of acrylic. The phenomena that you can charge certain materials by contact (like fur and acrylic) is called triboelectric effect.

Coulomb's law states that the interaction force between two point charges Q_1 and Q_2 is given by,
(1) $F = k\,\frac{Q_1 Q_2}{r^2}$,
where $k = 8.99 \times 10^9\ \mathrm{Nm}^2 / C^2$ is a constant, the direction of the force F is along the line between the charges. Negative force means attractive force and vice versa. Meaning that the like charges repel and opposites attract. r is the distance between the point charges. A point charge approximation is valid if the size of the charge carrying object is much smaller than r.

Capacitors, A Short Review

A capacitor is a device made of usually two conductors. The point of making a capacitor is to hold charge. The capacitance of a capacitor is defined by the amount of charge it holds when 1V voltage is applied to it,
(2) $C = Q / V$.
The unit for the capacitance is Farad denoted by F. A large capacitor in an electric circuit can be about μF or 10^{-6}F.
The capacitance depends on capacitor's geometrical shape and the dielectric material used inside it.

Discharging a conducting sphere: Intuitively speaking, capacitance shows how much room a single charge has when sitting on the capacitor. Lower capacitance means less room which is less comfortable. Remember that the like charges repel. A conducting sphere can be thought of as a capacitor which has one conductor

which is the sphere itself and another conductor which is at infinity. In any case, the capacitance of the spheres we will use in this lab are pretty small, about R/k = 2.8 pF where R is the radius. This means that the charges are really packed on top of them and are quite “unhappy” (high potential energy).
Now if you connect this sphere to a large 10μF capacitor, almost all the charges will leave the sphere and sit on the larger capacitor. This would allow you to measure the initial charge on the sphere (the final charge on the sphere is practically zero). You simply need to measure the voltage and use,
(2’) $Q = C\,V = (10\,\mu\text{F})\,V$.
Remember that (1F)×(1V) = 1 C. To measure the voltage one can use a DC voltmeter.

Dialog:

Question 1.
- If a sphere has a charge of +2 C on it, what will be the electrostatic force exerted on a second sphere with a charge of +1 C, at a distance of 20 cm? Is the force repulsive or attractive?

Answer 1.
For a sphere, the force outside the sphere is the same as the force that would be exerted considering the sphere as a point charge.

Hence, the force between the two spheres would simply be kq1q2/r^2 = 4.5×10^{11} **N** (calculation shown in the code below)

This is a very large force!

In[1]:=
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(* This is an Input cell in case you need *)
(9 * 10^9 * 2 * 1 ) / (0.2^2)
```

Out[1]= 4.5×10^{11}

Question 2.
- In the lab experiment, a charged metal sphere with charge Q is touched by a second metal sphere of the same radius but uncharged. What are the final charges on each sphere? Explain.

Answer 2.
When two metal spheres come in contact, one charged and the other uncharged, the charge gets distributed on the surface of the two sphere’s such that both the surfaces are at the same potential.

Since potential for a sphere at the surface is kQ/r,

Q will distribute into the 2 spheres as q1 and q2 such that kq1/r1 = kq2/r2 and q1+q2=Q ⇒ q1/r1 = (Q-q1)/r2
⇒ q1 = r1Q/(r1+r2) and q2 = Q-q1
The specific distribution would depend on the relative size of the spheres. For instance, <u>if the spheres were of the same size</u>, q1=q2, implying the charges would be distributed evenly into <u>Q/2, Q/2.</u>

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(* This is an Input cell in case you need *)
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Question 3.
- In the lab experiment, we have two charged spheres, sitting at a distance 10 cm apart from each other. We touch one of the spheres with a wire connected to a capacitor and deplete its charge into the 10μF capacitor. We read the capacitor voltage to be V_1 = 9.3 mV. Now we discharge the capacitor by connecting its plates together. Then we do the same with the other sphere, and measure V_2 = 8.1 mV. Using this data, estimate the initial electrostatic force between the spheres before emptying their charges into the capacitor.

Answer 3.
C=Q/V

So by definition, The charge Q on the capacitor stored per unit voltage (V) applied/attached across it is 10μC.

Hence, V = Q/C
So Q1= V1C and Q2 = V2C (Calculations below in the code - just plugged in the values)

Hence, by coulomb's law (since the force outside the spheres are applied as if caused by point charges),
<u>Assuming 10cm is the distance between the centres of the spheres</u>

F = kQ1Q2/r^2 = 0.007533 N

In[5]:=
```
(* This is an Input cell in case you need *)
Q1 = 9.3 * 10^(-3) * 10 * 10^(-6)
Q2 = 8.1 * 10^(-3) * 10 * 10^(-6)
10 * 10^9 * Q1 * Q2 / (0.1^2)
```

Out[5]= 9.3×10^{-8}

Out[6]= 8.1×10^{-8}

Out[7]= 0.007533

Table X. Copy All Your Final Results.

In[8]:=
```
Grid[{{Text["Table X. Final Answers, Lab 3 Prerequisite"], SpanFromLeft},
  {"Q1. F (N)", "Q2. final charge on first sphere, Q1",
   "Q2. final charge on second sphere, Q2", "Q3. F (N)"},
  {"4.5 * 10^11", "Q/2", "Q/2", "0.007533"}
 }, Frame → All]
```

Out[8]=

Table X. Final Answers, Lab 3 Prerequisite			
Q1. F (N)	Q2. final charge on first sphere, Q_1	Q2. final charge on second sphere, Q_2	Q3. F (N)
$4.5 * 10^{11}$	Q/2	Q/2	0.007533

Rutgers 276 Classical Physics Lab
"Electrostatics"