

Introduction to Discussion Sessions In the context of Electrostatics: Coulomb's Law

What's the purpose of discussion/lab sessions?

Your experience of the world tells you a lot about how things move and why. You've used the terms accelerate, energy, work, momentum, accelerate, heat, etc. What you probably don't realize is that many ways in which you currently understand the world are physically incorrect! It takes a lot of work to untangle your correct physical understanding from the misconceptions and then weave the information into a coherent (and correct) understanding of the physical world. The discussion/lab sessions give you an opportunity to do this work with guidance from your classmates and teaching assistant. Physics education research shows this an effective and efficient way to learn physics, even if it means spending 4 hours per week in these sessions!

Important note: *Very rarely will you be able to complete an entire worksheet within the discussion session. Use the remaining activities and problems when you study outside of class.*

Student Learning Objectives¹

Student learning objectives give the goals for the discussion session. Each activity in discussion and lab is designed to help you achieve these objectives.

1. Meet teaching assistant and classmates.
2. Work in small groups of 3-4.
3. Create a concept map with the guidance of your teaching assistant.

Below are the student learning objectives for Electrostatics.

1. To become familiar with basic electric phenomena.
2. To learn the *charge model* and apply it to conductors and insulators.
3. To understand polarization and the attraction between neutral and charged objects.
4. To understand and use Coulomb's Law for point charges.
5. To recognize and use the principle of superposition for electric forces.

Common Misconceptions¹

The worksheets will always list some of the common misconceptions students make. Look through them; see if any affect your understanding of physics. Use the discussion activities and your group members to help correct your understanding of physics. Don't suffer from anything on the list? Excellent, now help your group-mates!

Physics education research shows that the following are widely held misconceptions:

- Many students believe insulators cannot be charged.
- Students do not distinguish between an object (insulator/conductor) and its charge state (charged/neutral).

¹ R. Knight, *Five Easy Lessons: Strategies for Successful Physics Teaching*, Addison Wesley, 2004.

- Students think of charge as an *object* rather than as a property of matter.
- Students don't recognize charge conservation.

Discussion Activities

These activities will be a combination of individual and group work, conceptual and quantitative problems, thinking and hands-on experiments.

Concept Map

1. Create a concept map for motion that point charges.
 - a. (*On your own*) Make sure to include written definitions (*in your own words*), variables, units, implications of signs, formulas, and anything else that will help you understand positive and negative charges and the Coulombic (aka electrostatic) force between them.
 - b. (*With the group*) Address any misconceptions you have, and add to the concept map throughout discussion and as you study.

Study Guide Volume 2: Sections 21.1 – 21.3

Pay particular attention to the Common Pitfalls!

Additional Problems

Try each of the following problems on your own and then compare with your group.

1. Coulomb's Law for the electrostatic force between two point charges is

$$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} = \frac{kq_1 q_2}{r^2}. \text{ This looks a lot like Newton's law for the gravitational}$$

force between two point masses: $F = \frac{Gm_1 m_2}{r^2}$. And indeed, because both forces are

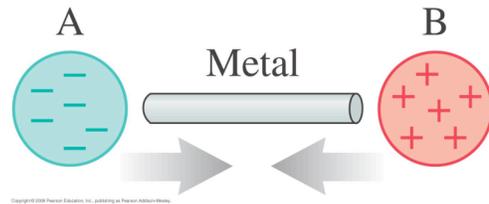
" $1/r^2$ forces," there are some mathematical similarities between them. However, all similarities aside, can you think of any important *differences* between electrostatic forces and gravitational forces?

2. Four equal charges q are on the corners of a square of side-length a .
 - a. In what direction do you intuitively expect the net force to be on the charge in the upper right corner? Explain. Work this problem conceptually, without using Coulomb's Law.
3. Four lightweight balls A, B, C, and D are suspended by threads. Ball A has been touched by a plastic rod that was rubbed with wool. When the balls are brought closer together, without touching, the following observations are made
 - a. Balls B, C, and D are attracted to ball A.
 - b. Balls B and D have no effect on each other.
 - c. Ball B is attracted to ball C.

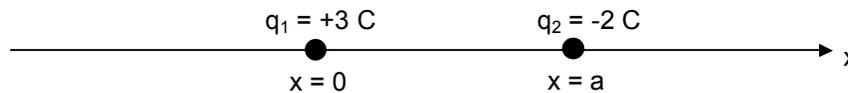
What are the charge states (positive, negative, neutral) of balls A, B, C, and D? Explain.

4. A lightweight metal ball hangs by a thread. When a charged rod is held near, the ball moves toward the rod, touches the rod, and then quickly “flies away” from the rod. Explain this behavior.
5. A negatively charged electroscope has separated leaves.
- Suppose you bring a negatively charged rod close to the top of the electroscope, but not touching. How will the leaves respond? Explain.
 - How will the leaves respond if you bring a positively charged rod close to the top of the electroscope, but not touching?
 - Use both charge diagrams and words to explain.

6. The two oppositely charged metal spheres in the figure below have equal quantities of charge. They are brought into contact with a neutral metal rod. What is the final charge state of each sphere of the rod? Use both charge diagrams and words to explain.



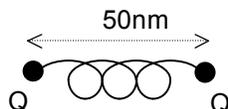
7. Two point charges $q_1 = +3 \text{ C}$ and $q_2 = -2 \text{ C}$ are fixed in place along the x -axis, as shown.



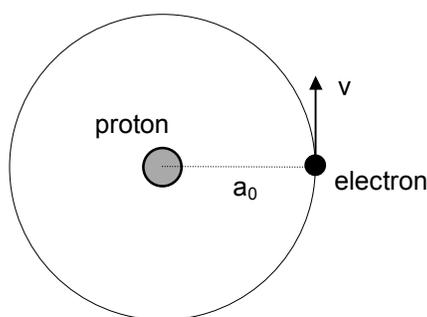
You have in your hand another point charge q , and you want to place it somewhere on the x -axis. But you want to place it at a point where it will *stay*. That is, you want to place it at a point where it will feel *no net force* due to the fixed charges q_1 and q_2 .

- Is there any point on the x -axis *in between* the two fixed charges, where you could place your charge q and it would remain at rest? Explain. Does your answer depend on whether your charge q is positive or negative? Why or why not?
- Is there any point on the x -axis to the *right* of the two fixed charges, where you could place your charge q and it would remain at rest? Explain. Does your answer depend on whether your charge q is positive or negative?
- Is there any point on the x -axis to the *left* of the two fixed charges, where you could place your charge q and it would remain at rest? Explain. Does your answer depend on whether your charge q is positive or negative?

8. A 50 nm long unstretched DNA molecule is attached at either end to two charged polystyrene beads that are held in place by optical traps. When the traps are switched off the spacing between the beads increases by 10%. Assuming the DNA acts as a spring with spring constant $k = 10^{-10}$ N/m and that the beads have identical charges.



- Find an equation that will determine the length D of the spring, once the charges have come to rest.
 - Knowing the increase in length compute the charges on the beads.
 - Can you tell whether they are positive or negative?
9. Returning to the situation described in Question 7 above, find the point(s) on the x -axis where your point charge q would remain at rest.
10. A hydrogen atom consists of a massive proton with a much lighter electron orbiting around it. In the “ground state” of the atom, the electron orbits the proton at a distance $a_0 = 5.3 \times 10^{-11}$ m.



$$m_p = 1.7 \times 10^{-27} \text{ kg}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$q_p = 1.6 \times 10^{-19} \text{ C [usually denoted } e]$$

$$q_e = -1.6 \times 10^{-19} \text{ C [usually denoted } -e]$$

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$$

- At this separation, what is the magnitude of the *gravitational* force between the proton and the electron?
- At this separation, what is the magnitude of the *Coulomb* force between the proton and the electron?
- Which of these two forces is negligible in comparison with the other?
- In the ground state, how many times per second does the electron orbit the proton?