Coulomb's Law: A Quantitative Look at Electric Force

Concept covered in activity

We will look at the models and equations that deal with electric force. Specifically, we will explore Coulomb's Law and the electric field model.

Grade level or other prerequisites for activity

This lesson is designed to fit into a high school physics unit on electricity. Students should have already been introduced to static electricity and charges, as well as had a quantitative introduction to electric force.

Standards:

Colorado Department of Education High School Physical Science Standard 5: Energy exists in many forms such as mechanical, chemical, electrical, radiant, thermal, and nuclear, that can be quantified and experimentally determined.

National Physical Science K-12 Content Standard: As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes: Evidence, models, and explanation, and Constancy, change, and measurement.

Learning objectives:

Students should be able to demonstrate their understanding of Coulomb's law and the way it governs the interaction between charged particles, by effectively describing these ideas using words and sketches.

Materials

- One guide sheet for each student
- Computer with simulation downloaded
- Science Notebook

Instructional planning

The EJS Coulomb Force simulation can be downloaded from the comPADRE National Digital Library: http://www.compadre.org/OSP/items/detail.cfm?ID=9683

Like any activity involving computers, proper preparation and testing is a must.

Procedure/activity

	Student Activity	**Teacher Activity**
Engage	Consider the phenomenon of charge interaction through the lens of the knowledge they have acquired in the electronics unit to date. Connect their knowledge of charge interaction to the physical law that governs this action: Coulomb's law.	Introduce the Coulomb force using the Charge introduction. Complete as a whole group with a fast pace (about 15 minutes) and with students using their science notebooks. How do charged particles interact with each other? … have students write down initial ideas about charged particles. Questions to elicit specific ideas: -How many types of charges? (two: positive and negative) -What attracts? (opposite charges; while like charges repel) -If the charges are bigger, what do you think will happen to the force between the charges? (bigger) -If the charges are close to each other, what happens to the force? (bigger) All of this is described by Coulomb's Law: The force between two charged particles is $F = kq_1q_2/d^2$ and this force is a vector that points along a line connecting the particles.
Explore	Explore the simulation. Generate curiosity. Familiarize themselves	Have students work in pairs and open the EJS Coulomb Force

	with the interface.	simulations. Allow students about 5 minutes to explore the simulation.
Explain	Experiment with the simulation to uncover answers to the guide.	Ask students to reset the simulation and begin with questions in the guide below. Circulate to answer questions and provide any necessary scaffolding.
Elaborate	Consolidate acquired knowledge of Coulomb's and how it affects charged particles. Convey this knowledge through sketching and writing.	Ask them to write a brief description or make sketches to explain Coulomb's law and how Newton's 3^{rd} law applies to charged particles.
Evaluate	Students will be able to use the thorough feedback from their assessments to evaluate and expand their understating of the concepts.	Circulate to check that the Introduction and Coulomb Force Worksheet is completed and stapled into the science notebook. The science notebook will be collected for grading.

Assessment

All of the assessments in this lesson are designed to be formative in the context of the electronics unit plan, which will end with a formal summative assessment. The three assessments are the Introduction: Charged Particles prompt, the Activity Guide: EJS Coulomb Force Simulation work sheet, and the written/sketched description of Coulomb's law. All of these are meant to be returned with meaningful feedback. Please find the Charged Particles prompt, and the Activity Guide: EJS Coulomb Force Simulation work sheet below.

Anticipated misconceptions/alternative conceptions

It can initially be difficult for students to separate their ideas about charges from their ideas about voltages and currents.

Accommodations/modifications of activity for any special needs students (special education, ELL, and gifted/talented)

The instructor should have the opportunity to address students who are in need scaffolding individually while they are working with the simulation. At this time, the instructor may give extra help as it is deemed necessary. The EJS Coulomb Force Simulation work sheet includes a “Further Exploration” which advanced students can be asked to complete.

This lesson was adapted by Ben Thompson from the lesson plan, Coulomb Force Simulation, written by Anne J Cox and edited by Mario Belloni and Wolfgang Christian.

Introduction: Charged Particles

There is a force between charged particles. Describe the force as completely as possible as you understand it. Questions to consider: does it require contact between particles? Are there different types of charge and how do they interact? Does it depend on the distance between charged particles?

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Introduction: Charged Particles Answer Key

There is a force between charged particles. Describe the force as completely as possible as you understand it. Questions to consider: does it require contact between particles? Are there different types of charge and how do they interact? Does it depend on the distance between charged particles?

answers from students will vary: positive and negative charges,

opposites attract, like repel, force is smaller when further away

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Activity Guide: EJS Coulomb Force Simulation

In this simulation, you can move charged particles around and see the force vector (due to the Coulomb force), change the amount of charge on a particle (the size of the particle changes to show you this) and add charged particles (click on the "Add Charge" button).

1. Run the Applet file on-line OR run the simulation by double-clicking on the ejs_electric_sampler.jar and then navigating to the Coulomb Force simulation and run the simulation by double-clicking on the green arrow.
2. Move the red and green charges around and note what happens to the force arrows and the force. Do these particles have the same charge or opposite charge? How can you tell?

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   ____

3. Reset the simulation. Both the red and green charges have the same magnitude (size) charge. How does the force on the red charge compare to the force on the green charge?

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4. Now, use the red slider to change the charge on the red charge (its size changes to remind you that it is a "bigger" charge). What happens to the force on the red charge? The force on the green charge?

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   Sketch your configuration below and record the force on each particle:

5. Which experiences the largest force?

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6. Although many students find this surprising, think back to Newton's 3rd law and use it to explain why they should experience the same force:

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7. Set the red back to q=1. If you change the size of the green charge, what do you expect will happen? Why? Try it and explain if you were correct or not.

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8. The interaction you have observed is described by Coulomb's force law. The size of the Coulomb force law is given by $F = kq_1q_2/r^2$ where k is a constant, q_1 and q_2 are the charges of the two interacting particles and r is the distance between the two particles. Explain how this matches what you have observed in the simulation.

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9. What is the direction of the Coulomb force?

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Further Exploration (Vector nature of Coulomb Force):

10. Since force is a vector, if you add a third charge, you should be able to arrange the charges so that the force on one of the charges is zero (no arrow) while the force on the other two is non-zero. Reset the simulation and add another charge. Move the charges around until the red charge has no force on it. Sketch your configuration below:

11. In this configuration, if you increase the charge of the red charge, will it experience a force? Try it and explain.

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12. What if you change the green or blue charge, will the force on the red charge remain zero? Try it and explain.

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13. Add some more charges and see if you can keep the force on the red charge at zero. Sketch your configuration:

14. What is wrong with the following statement from a student?

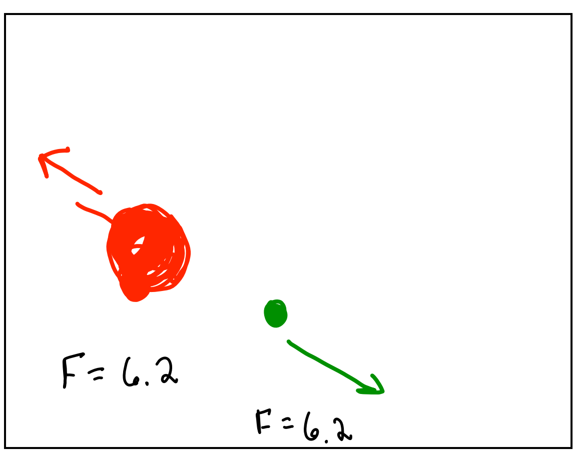
"When there are three charges (q=1 for all), the force on all three charges should be bigger than when there were only two charges (q=1 on each) because there is now a bigger total charge and the Coulomb force is proportional to charge."

Activity Guide: EJS Coulomb Force Simulation-Answer Key

In this simulation, you can move charged particles around and see the force vector (due to the Coulomb force), change the amount of charge on a particle (the size of the particle changes to show you this) and add charged particles (click on the "Add Charge" button).

1. Run the Applet file on-line OR run the simulation by double-clicking on the ejs_electric_sampler.jar and then navigating to the Coulomb Force simulation and run the simulation by double-clicking on the green arrow.
2. Move the red and green charges around and note what happens to the force arrows and the force. Do these particles have the same charge or opposite charge? How can you tell?
   _ same sign because they repel (can not tell if positive or negatively charged) _
3. Reset the simulation. Both the red and green charges have the same magnitude (size) charge. How does the force on the red charge compare to the force on the green charge?
   _same____
4. Now, use the red slider to change the charge on the red charge (its size changes to remind you that it is a "bigger" charge). What happens to the force on the red charge? The force on the green charge?
   __force on both increases (but have the same value)_________________

   Sketch your configuration below and record the force on each particle:



5. Which experiences the largest force?
___same force on both ____

6. Although many students find this surprising, think back to Newton's 3rd law and use it to explain why they should experience the same force:
________ Answers will vary: 3rd law: force on one object is equal (and opposite in direction) to force experienced by other object: red and green experience "equal and opposite" forces so Coulomb's law is consistent with Newton's 3rd law (as it should be) ____________________________

7. Set the red back to q=1. If you change the size of the green charge, what do you expect will happen? Why? Try it and explain if you were correct or not.
______same thing as before—it doesn't matter which charge is bigger___

____

8. The interaction you have observed is described by Coulomb's force law. The size of the Coulomb force law is given by $F = kq_1q_2/d^2$ where k is a constant, q_1 and q_2 are the charges of the two interacting particles and d is the distance between the two particles. Explain how this matches what you have observed in the simulation.
_____answers will vary: in simulation, force decreases as red and green are further apart (if you double the distance the force decreases by a factor of four, the force depends on the value of both the charges… _____________

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9. What is the direction of the Coulomb force?
___points along the line connecting charges (away from charges) ________

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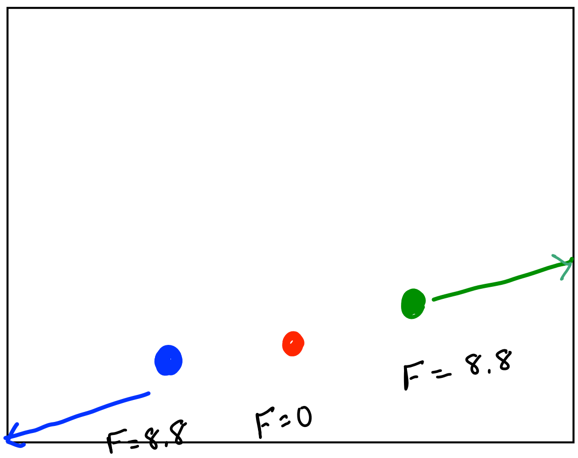
Further Exploration (Vector nature of Coulomb Force):

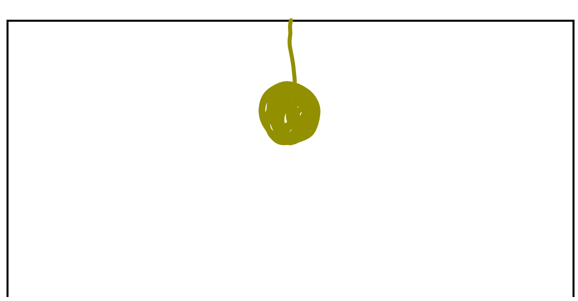
10. Since force is a vector, if you add a third charge, you should be able to arrange the charges so that the force on one of the charges is zero (no arrow) while the force on the other two is non-zero. Reset the simulation and add another charge. Move the charges around until the red charge has no force on it. Sketch your configuration below:

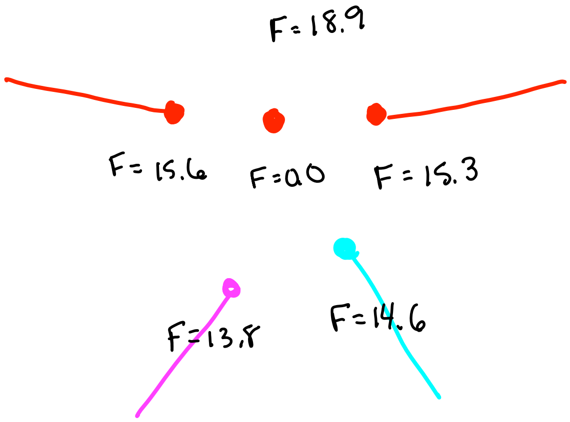


11. In this configuration (force on red equals zero), if you increase the charge of the red charge, will it experience a force? Try it and explain.
________still zero; force on red due to green increases, but so does the the force on red due to blue and they still cancel out ____________________

12. What if you change the green or blue charge, will the force on the red charge remain zero? Try it and explain.
_______no; this time force on red due to green (or blue) increases, but balancing force on red due to blue (or green) does not increase _________

13. Add some more charges and see if you can keep the force on the red charge at zero. Sketch your configuration:





14. What is wrong with the following statement from a student?

"When there are three charges (q=1 for all), the force on all three charges should be bigger than when there were only two charges (q=1 on each) because there is now a bigger total charge and the Coulomb force is proportional to charge."

_______answers will vary: force is a vector so you have to take into account the direction of force—it is possible to increase the charge (by adding more charges) but reduce the force on a particular particle (as in the case where the force on the red charge is zero) _______________________