Science Objectives

- Students will explore the force two charges exert on each other.
- Students will observe how the force depends upon the magnitude of the two charges and the distance separating them.
- Students will develop the equation for Coulomb's law using their observations.

Vocabulary

- attract
- charge
- Coulomb (used as a unit)
- distance
- force
- inverse square
- magnitude
- Newton (used as a unit)
- ratio of forces
- repel

TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Use a minimized slider

About the Lesson

- This lesson has students explore Coulomb's law by manipulating the magnitude of two charges and the distance separating them.
- As a result, students will:
  - Observe that charges with like signs repel and charges with opposite signs attract.
  - Relate the magnitude of the force the charges exert on each other to the product of the two charges and to the inverse square of the distance separating them.
  - Develop the equation for Coulomb's law.

Tech Tips:

Make sure that participants understand how to use the minimized sliders and the play, pause, and reset buttons.

Lesson Materials:

Student Activity

- Coulombs_Law_Student.doc
- Coulombs_Law_Student.pdf

TI-Nspire document

- Coulombs_Law.tns

TI-Nspire™ Navigator™

- Send out the *Coulombs_Law.tns* file.
- Monitor student progress using Screen Capture.
- Use Live Presenter to spotlight student answers.
- Collect the student .tns file and evaluate student understanding.

Activity Materials

- *Coulombs_Law.tns* document
- TI-Nspire™ Technology
- Student Activity Handout

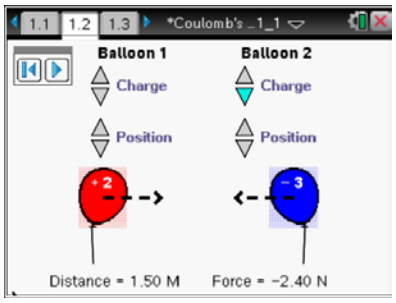
Discussion Points and Possible Answers

Move to page 1.2.

1. This page gives students some background and some instructions for the simulation on page 1.3. On the simulation page, students will use minimized sliders to set the amount and sign of the charge on each of the two balloons. The charge is measured in multiples of 10 µC. The sliders allow the charges to be set between +/– 5 (×10 µC). Students will also be able to change the position of each balloon. In this simulation, attractive forces are designated with a negative sign, and repulsive forces are designated with a positive sign.

Move to page 1.3.

Using this simulation, students will set up several different scenarios and record the force between the charges in each case. They will then compute the ratio of the force in a particular scenario to a standard value designated as F_1. The ratios should help students understand how the force depends on both the values of the charges and the distance separating them.



Have students answer Questions 1-20 on the activity sheet. (A few of the questions are included in a multiple-choice format on pages 1.5 through 1.10 in the .tns file as a review.) Students should complete the questions in the activity sheet first.)

Q1. Give both balloons a large positive charge. Describe the directions of the forces that result.

Suggested Answer: The force on a charge is directed away from the other charge.

Q2. Press the play button and describe what happens to the balloons and the forces they exert on each other. (Press the pause button and then the reset button before replaying.)

Suggested Answer: The balloons move away from each other and the forces decrease.

Q3. Give one balloon a negative charge by clicking on the down arrow until the number becomes negative. How does this change the directions of the forces?

Suggested Answer: The force on a charge is directed toward the other charge.

Q4. Press the play button and describe what happens to the balloons and to the forces they exert on each other.

Suggested Answer: The balloons move toward each other and the forces increase.

Q5. Describe the directions of the forces when both balloons are negatively charged.

Suggested Answer: The balloons repel each other.

Q6. Give both balloons a charge of +1. Separate the balloons by a distance of 1 m. Record the magnitude of the force. In the next several questions, you will compare other forces to this one.

Answer: F_1 = 0.9 N

Q7. Change the charge of Balloon 1 to +2. Record the new force as F_2. Calculate the ratio of F_2:F_1.

Answer: F_2 = 1.8 N; $\frac{F_2}{F_1} = 2$ Doubling one charge doubles the force.

Q8. Change the charge of Balloon 2 to +2. Record the force as F_3. Calculate the ratio of F_3:F_1.

Answer: F_3 = 3.6 N; $\frac{F_3}{F_1} = 4$ Doubling both charges quadruples the force.

Q9. Give Balloon 1 a charge of –3, and give Balloon 2 a charge of +4. Record the force as F_4 and calculate the ratio of F_4:F_1.

Answer: F_4 = –10.78 N; $\frac{F_4}{F_1} = -12$

Q10. Based on your observations in the previous questions, summarize the relationship between the magnitude of the force and the values of the charges.

Suggested Answer: The force is proportional to the product of the two charges.

Q11. Change the charge on both balloons back to +1. Move the balloons so that the separation between them is 2.0 m (twice the original distance). Record the force as F_5, and calculate the ratio F_5:F_1.

Answer: F_5 = 0.22 N; $\frac{F_5}{F_1} = \frac{1}{4}$

Q12. Move the balloons so that the distance between them is now 3.0 m (three times the original distance). Record the force as F_6 below, and calculate the ratio F_6:F_1.

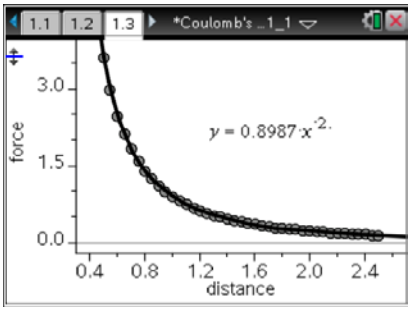
Answer: F_6 = 0.10 N; $\frac{F_6}{F_1} = \frac{1}{9}$

Q13. Using your answers to questions 11 and 12 as a guide, predict the force between the balloons when they are separated by 0.5 m. Explain how you made your prediction. Check to see if you are correct.

Suggested Answer: F = 3.6 N. The new distance is half of the original distance. The force is proportional to the inverse square of the distance. Thus the force is 4 times larger than the original force.

Students will now explore in more detail the relationship between the force the balloons exert on each other and the distance separating them.

2. Students should separate the balloons on page 1.3 by 0.5 m and give each a charge of +1. They should then press the play button ▶, and observe the motion of the balloons.



Move to Page 1.4.

3. As the balloons move apart, the distance and force data are automatically recorded and graphed on page 1.4. Students may watch the graph as it is plotted by moving to page 1.4 after pressing the play button ▶.

Q14. Based on your answers to questions 9 and 10 and the shape of the graph, how would you describe the relationship between the force and the distance between the charges? (Students may need to rescale the graph by pressing **Menu > Window/Zoom > Zoom – Data**.)

Suggested Answer: The force decreases as distance increases. Based on the ratios from the earlier questions, $F \propto \frac{1}{r^2}$.

Q15. If the equation is not displayed on the screen, click the curve to make it active. What is the exponent in the equation? Does this match the relationship you predicted in question 12? Explain.

Answer: The exponent is –2. This means there is an inverse square relationship between force and distance.

Q16. Write the equation of the curve. Remember that force is plotted on the *y*-axis of the graph and distance is plotted on the *x*-axis. When you write the equation, substitute *F* for *y* in the equation, and substitute *r* for *x*. Write the equation as a fraction instead of having a negative exponent. Describe the relationship between the force *F* and the distance *r*.

Answer: $F = \frac{0.8987}{r^2}$ The force is inversely proportional to the square of the distance between the charges.

Q17. In the first part of this activity, you observed that the force two charges exert on each other is proportional to the product of the charges. The number in the equation you found in question 16 is equal to $k \times q_1 \times q_2$ where *k* is a special constant in physics. In this case both q_1 and q_2 are equal to 1×10^{-5} C. Calculate the value of the constant *k* using the number from the equation and the values of q_1 and q_2. Show your work.

Answer:

$$0.8987 = kq_1q_2$$
$$0.8987 = k\left(1\times 10^{-5}\right)\left(1\times 10^{-5}\right)$$
$$k = 8.987\times 10^{9}$$

TI-Nspire Navigator Opportunities

Make a student a Live Presenter and have them demonstrate how to calculate the constant.

Q18. Return to the simulation on page 1.3. Press the reset button to clear the data. Give each balloon a charge of +2, and separate them by 0.5 m. Press the play button to collect a new set of data. Look at the graph on page 1.4. What is the new equation? Calculate the constant, *k*, in the same manner as you did in the previous question. Remember q_1 and q_2 are now 2×10^{-5} C.

Answer: $F = \frac{3.5948}{r^2}$; $3.5948 = k\left(2 \times 10^{-5}\right)\left(2 \times 10^{-5}\right)$ $k = 8.987 \times 10^9$

Q19. Write a general equation using the constant, *k,* to calculate a force, *F,* that exists between two charges, q_1 and q_2, separated by a distance, *r*. This equation is known as Coulomb's Law. Describe the relationships between the variables expressed in the equation in a sentence or two.

Answer: $F = \frac{kq_1q_2}{r^2} = \frac{\left(8.987 \times 10^9\right)q_1q_2}{r^2}$ The force is directly proportional to the product of the two charges and inversely proportional to the square of the distance separating them.

Q20. Use your equation to calculate the force when $q_1 = 4 \times 10^{-5}$ C, $q_2 = 5 \times 10^{-5}$ C, and r = 1.50 m. You may use the Scratchpad to make your calculation. Show your substitution of the numbers and your answer below.

Answer: $F = \frac{\left(8.987 \times 10^9\right)\left(4 \times 10^{-5}\right)\left(5 \times 10^{-5}\right)}{\left(1.50\right)^2} = 7.99N$

Move to page 1.5.

After students answer the questions on this activity sheet, have them answer the questions on pages 1.5–1.10 in the .tns file to review what they have learned.

Extension

Have students make up their own problems using the simulation to practice using Coulomb's law. Students may also need more practice using proportions to determine how much the force changes when changes are made in either of the charges or in the distance separating them.

Wrap Up

You can have students answer the questions in the .tns file as additional reinforcement and review. When students are finished with the activity, pull back the .tns file using TI-Nspire Navigator. Discuss activity questions using Slide Show.

Assessment

- Formative assessment will consist of questions in the activity sheet and the .tns file. The questions will be graded when the .tns file is retrieved. The Slide Show will be utilized to give students immediate feedback on their assessment.
- Summative assessment will consist of questions/problems on the chapter test.