All Charged Up

Electrostatics

Danny Mattox, Danny Mattox, Quentin Biddy, Kristi Adams
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Grade Level	9th – 12th Grade	**Time Frame**	2-4 class period(s)
Course	Physics	**Duration**	110 minutes

Essential Question

How is static charge generated and how do isolated charges separated by a distance relate to force?

Summary

Students will be able to explain the fundamental concepts involved in electrostatics, such as charge, friction, conservation of charge, laws of attraction, and Coulomb's Law.

Snapshot

Engage

Students watch a short video of a dog that has been charged and write a 20 word GIST statement to describe the physics of what they see in the video.

Explore

Students develop a method to levitate a ring made of grocery bag material using a balloon and paper towel. Students will write a 50-word GIST statement, explaining what happened using their academic vocabulary.

Explain

Students share GIST statements, and the teacher clarifies and formally defines terms and relationships involved in electrostatics including conservation of charge and Coulomb's Law.

Extend

Students apply mathematical relationships to electrostatic problem solving and research additional applications of electrostatics.

Evaluate

Students will explain the process of lightning using academic vocabulary from the lesson.

Standards

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Oklahoma Academic Standards (Physics)

PH.PS1.8.DCI.2: The total number of neutrons plus protons does not change in any nuclear process.
PH.PS3.2.DCI.2: That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

Attachments

- Lesson Slides—All Charged Up.pptx
- Picture—All Charged Up.png
- Practice Answers—All Charged Up.docx
- Practice Answers—All Charged Up.pdf
- Practice—All Charged Up - Spanish.docx
- Practice—All Charged Up - Spanish.pdf
- Practice—All Charged Up.docx
- Practice—All Charged Up.pdf

Materials

- Grocery bags
- Balloons (large, round type works best)
- Scissors
- Paper towels
- Picture of levitating bag and balloon (attached)
- Practice Handout (attached)
- Lesson Slides (attached)
- Large, poster-sized paper
- Markers, colored pencils, crayons, etc.

Engage

Lesson Preparation Notes

This lesson involves how charge is generated using conservation of charge and how isolated charges separated by a distance interact with one another. Charge is a fundamental unit of matter (variable symbol is q and unit is C for coulomb). The value of a single charge is e = 1.6 x 10-19 C. Total charge of an object is found by multiplying the number of charges by the value of a single charge (q = ne). Objects become charged by the reorientation of electrons. There are several ways of charging objects: friction, induction, and polarization. In this lesson, students are charging bags and balloons using friction. If an object gains electrons it is considered to be negative, and if the object loses electrons it is considered to be positive. While an object gains or loses its electrons, those electrons are transferred to another object, thus conserving charge. When two or more isolated charges are separated by a distance, either an attracting or repelling force exists that is proportional to the product of their charges and inversely proportional to the square of the distance between them (Coulomb's Law). The direction of the force is determined by the charges associated with the objects and its applicable laws of attraction. If the objects have opposite charges they will attract but if their signs are like then they will repel.

DAY 1 Show students the CuteWinFail: Static Dog video (it is recommended to turn off the annotations of this video—found under Settings designated by the gear symbol in the lower right-hand corner of the video box—before playing as they can obstruct the video itself). After the video, ask students to write a 20-word GIST or a Tweet Up summarizing the physics in the video. A GIST statement is a statement, typically 20-words, that sums up the student's understanding of the topic.

Embedded video

https://youtube.com/watch?v=aO-phqmyqdY

Possible GIST Or Tweet Up Responses

The dog became statically charged due to the friction between the blanket and the dog's fur. The dog's fur became charged because of the blanket rubbing, like when you shuffle across carpet in your socks then shock someone.

As students share their GIST or Tweet Up statements, write a list of the electrostatic terms on the board or on a large sheet of paper so they are visible to the class. Some terms to listen for are static, charge, friction, electrons, negative, positive, attract, repel, electric field, and force. They may only use two or three terms from this list. That is OK. The list will be expanded during the Explore section.

Teacher's Note

The dog's hair stands up because friction caused a transfer of electrons from the dog to the blanket. This leaves the dog with a net positive charge and the blanket with a net negative charge. However, the system conserves charge so there was not a net loss or gain of electrons by the system. The system is defined to be blanket and dog.

Explore

Show students the attached **Picture** of the levitating ring and balloon. Tell students they have 20 minutes to accomplish the same thing they are seeing in the picture, using a balloon to levitate a ring.

Each student or group will receive a grocery bag with scissors, a balloon, and paper towels in it. Tell the students they are allowed to use any and all of the materials for their experiment. Avoid the temptation to tell them how to accomplish the task.

Teacher's Note

The easiest way to accomplish the task is to blow up the balloon and cut a ring out of the grocery bag. The ring should only be an inch or two wide. Then, rub the paper towel on the balloon repeatedly in the same direction and do the same thing with the grocery bag ring. Rubbing the bag and the balloon in the same direction will separate the electrons, inducing a charge. Both the ring and the balloon should have the same charge, therefore the objects will repel and the ring will appear to levitate.

Common Student Mistakes

Students may have too big of a strip of bag for the electrostatic force to be large enough to counteract the bag's weight. Students who do charge both objects will have limited success. If a group only charges the balloon, you may ask them to charge the bag in the same way and see if it affects their results. Students will have more success if they rub the paper towel against the bag in one direction only with the bag on a table. The balloon will also need to be rubbed using the paper towel to get the best results, not someone's shirt or head. If students are having limited success, you may want to ask them how they can get the bag to levitate higher. To do this, they should reduce the weight of the bag by making a smaller ring.

Once all of the groups have accomplished the task, have a class discussion on how the activity was similar and how it was different from the charged video in the Engage portion. During the discussion, add to the list of terms from the Engage portion. Some additional terms from the discussion may include repel, charge(d), force, and gravity (weight).

Teacher's Note

Students should introduce the idea of a force being present that is at least equal to the bag's weight, because it levitates. They should mention both objects had to be charged in the same way. This means the two objects have like charges and will repel.

Following the discussion, have students write a 50-word GIST statement incorporating all of the terms listed and explaining the relationships they observed in the activity.

Explain

Have students share their 20 word GIST or Tweet Up statements from the day before. At this time, begin to explain concepts as they relate to the students' ideas. Have students take notes or wait until after sharing the GIST or Tweet Up statements, then give students a more traditional opportunity to take notes using the attached **Lesson Slides**. It is most effective to do both, give notes as students share their ideas and afterward reinforce those main ideas by presenting the Lesson Slides. This way, there will be more opportunities to address misconceptions as students read their Tweets, students will feel as though they are contributing to classroom knowledge, and students will have two opportunities to get all the important information they need about this often confusing concept.

Teacher's Note

If you choose to give notes while they are reading their GIST or Tweet Up statements, be sure to structure them in a way that the main ideas build on each other. Don't start with the Coulomb's Law equation. (Example: The first student who shares a tweet says that the farther away the balloon and the ring are, the less force there is between them. You know that pertains to Coulomb's Law, but you are not ready to talk about it yet. Tell that student to share the tweet later and ask if there are any students that want to talk about the behavior of the balloon and ring, focusing on attraction versus repulsion.)

The notes should flow in the order they are arranged in the PowerPoint. Charged objects are positive or negative --> Charge is conserved --> laws of attraction --> Coulomb's Law. The Lesson Slides include presentation notes on most slides. As you go through each slide, you should be explicit in making connections to what the students experienced in the Engage and the Explore phases. The presenter notes on the PowerPoint help with this.

The laws of attraction state that objects with like charge will repel and charges with opposite charge will attract. Positive and negatives attract while positive-positive or negative-negative interactions will result in repulsion.

Coulomb’s Law states that a mutual force of attraction or repulsion exists between any two charges that is directly proportional to the product of their charges and inversely proportional to the square of the distance between them. This is similar to Newton’s Universal Law of Gravitation.

Fe = (k q1q2)/d2 where k is a constant = 9 x 109 Nm2/C2

Teacher's Note

For more information about Coulomb's Law and working problems, go to the Physics Classroom: Coulomb’s Law website.

Extend

Students should begin this phase of the learning cycle by doing the attached problems in small groups. The answers to the problems are on the last page of the handout, but students should not be given the answers to the questions prior to attempting them. Even if the group isn't exactly sure how to solve all the problems, they should at least try. After all the groups have finished the questions, assign each group one question, or one part of a multi-step question, that they will answer for the class. Then, have a class discussion in which the groups share the solution to the problem they were given.

Teacher's Note

Be sure all the correct answers are given to the students by the end of the discussion. Rather than just giving them the answer or having the groups simply state the correct answer when they share, be sure to explain how they got the answer. It may be a good idea to assign a group to answer a problem they have worked incorrectly, just so you can address any misconceptions they may have.

After all the questions are answered, show students the Electroscope Demo ScienceLibrary.info video. Pause it at 0:50. Explain that the device in the video is called an electroscope and it was invented hundreds of years ago to detect charge in objects. The stronger the charge, the greater the reaction of the leaves at the bottom of the device. Use an Exit Ticket with this prompt: "Based on what you've learned so far, explain what is happening and why it's happening." After prompting the students, show the video to the students again, stopping again at 0:50.

Embedded video

https://youtube.com/watch?v=Ngv2OlqFWXU

Teacher's Note

You will show the students the rest of the video in Evaluate, which will explain what is happening with diagrams and charges labeled.

Collect the exit tickets.

Evaluate

Read a few responses to the Exit Ticket question. Then, show the entire Electroscope Demo ScienceLibrary.info video. The second half of the video has areas of charge labeled.

For the final part, students will be researching lightning and sharing their information with each other. Place students in groups of 2-3 and give them a poster-sized sheet of paper. An over-sized Post-it or a piece of bulletin board paper will work well. Explain to the students that they will be doing a Gallery Walk at the end of the next class period based on this prompt: What is lightning? Students need to research lightning and provide a thorough answer on their poster using drawings, diagrams, labels, and text. They should include all the terminology from this lesson on their poster. The rest of the hour should be used for researching lightning online or in books. Students should use the next class period to finish their research, finish their posters, and do the gallery walk.

Teacher's Note

There are all kinds of lightning info available online. Students should know that many aspects of lightning remain a mystery. The article How Lightning Works provides some insight on that mystery.

Differentiations

Additional mathematical practice with Coulomb's Law may be necessary for students to gain fluency. The instructor may want students to build an electroscope using clay/holder, straws, and tape.

Resources

- Bone, A. (10 Feb. 2013). *Electroscope Demo ScienceLibrary.info* [Video]. YouTube. https://www.youtube.com/watch?v=Ngv2OlqFWXU
- cutewinfail. (2 Aug. 2011). *CuteWinFail: Static Dog* [Video]. YouTube. https://www.youtube.com/watch?v=aO-phqmyqdY&list=PL817636B09D2C9B80&index=22
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- K20 Center. (n.d.). Bell Ringers and Exit Tickets. Strategies. https://learn.k20center.ou.edu/strategy/125
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- K20 Center. (n.d.). Tweet Up. Strategies. https://learn.k20center.ou.edu/strategy/130
- The Physics Classroom. (n.d.). *Static Electricity - Lesson 3 - Electric Force*. The Physics Classroom. https://www.physicsclassroom.com/class/estatics/Lesson-3/Coulomb-s-Law