Investigation 1 – Why do some things stick together and other things don't?

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INVESTIGATION 1
Why do some things stick together and other things don't?

Overview

This investigation starts with an introduction to the driving question for the unit: Why do some clothes stick together when they come out of the dryer? *Throughout the investigation, students will begin to develop a conceptual model of electrostatic interactions by exploring how various charged objects (Scotch tape, balloons, rods of various materials, and a Van de Graaff generator) interact with one another. By the end of Investigation 1, the model will include positive and negative charges as well as patterns that can be used to explain and predict how charged objects interact with each other (i.e., opposite charges attract; objects of the same charge repel) and neutral and charged objects (regardless of charge) attract each other.. In later investigations, students will build upon their models of electrostatic interactions by incorporating electric fields and a qualitative view of Coulomb's law.*

The Performance Expectations (NGSS)

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.

Elements from NGSS	**Connections to this investigation**
Elements of Disciplinary Core Idea	
Elements of the core idea from the NGSS Performance Expectation	How this investigation builds toward the core ideas
Structure and Properties of Matter: • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms (NGSS Lead States, p. 94).	Students note patterns in how charged and neutral objects interact and use a simulation to develop a model explaining these observations.
Crosscutting concept	
Crosscutting concept from the NGSS Performance Expectation	How this investigation builds toward the crosscutting concept

Overview

Patterns: • Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82).	Students collect various data from demonstrations, experiments, and an interactive simulation. Students use the data to note patterns in how charged objects interact.
Science and engineering practice	
Science and engineering practice from the NGSS Performance Expectation	How this investigation builds toward the science and engineering practice
Using Mathematics and Computational Thinking: • Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ○ Use mathematical representations of phenomena to describe explanations (NGSS Appendix F p. 55).	Before students can develop mathematical representations, they must first understand the underlying concepts. If students learn the math before the concepts, they tend to solve problems using algorithms rather than reasoning. Therefore, this investigation does not address mathematical or computational thinking, but rather focuses on the underlying concepts to provide a strong foundation for later use of mathematical approaches .

Objective: Target Model

What should the student's conceptual model include?

- *Objects can be positively charged (+), negatively charged (-), or uncharged (neutral).*
- *Objects with the same charge repel each other; oppositely charged objects attract each other. Charged and uncharged objects attract each other regardless of whether the charged object has a positive or negative charge*

Background Knowledge

- *The source of electric charge is from negatively charged electrons and positively charged protons, which are within the atoms that make up all substances. However, this level of detail is not needed for this investigation. The atomic level source of charge will be explored later in the unit.*
- *Objects almost never have an equal amount of positive and negative charge. They may have areas that are positively charged and others that are negatively charged. However, to begin with, we will assume that objects are homogeneously charged, or neutral. We will also ignore the dimension and shape of the objects, and instead think of them as point-like objects.*
- *There are several demos that utilize a Van de Graaff generator (VDG). (See Appendix for more information about how this device works.)*

Activities

Activity 1.1	*What are some examples of things that stick together and things that don't?*	*45 min.*
Activity 1.2	*What are some patterns in how things stick together or push apart?*	*60 min.*
Activity 1.3	*What effect do charged objects have on uncharged objects?*	*60 min.*
Activity 1.4	*How do I know if something is positively or negatively charged?*	*90 min.*
Activity 1.5	*How does an object's charge affect its interactions with neutral objects?*	*60 min.*

Activity 1.1 What are some examples of things that stick together and things that don't?

SUMMARY

Discussion and demonstrations of electrostatic interactions will be used to engage students in the activity level sub-driving question, *What are some examples of things that stick together and things that don't?* and elicit new questions about electrostatic phenomena. Some phenomena will be familiar (rubbing a balloon on hair and sticking the balloon to the wall to illustrate attraction) and others will involve a Van de Graaff generator charging and repelling objects to illustrate repulsion.

LEARNING GOAL

Students will ask questions about phenomena observed in the classroom and in daily life that involve electrostatic interactions. (Clarification: Students are not expected to come to any consensus about the cause of these phenomena or even use terms like "electrostatic", "charge", "attract", or "repel" by the end of this activity. Students should just be speculating about the interactions and asking questions.)

Disciplinary core idea	Crosscutting concept	Science and engineering practice
In this activity students will explore phenomena that are related to the DCIs of *Structure and property: The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (NGSS Lead States, p. 249).* However, the goal of this activity is that students observe phenomena, discuss initial ideas, and ask questions. There are no specific content ideas that students should develop in this activity.	*Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. (NGSS Appendix G p. 83)	*Asking questions and defining problems:* Ask questions • that arise from careful observations of phenomena, or unexpected results, to clarify and/or seek additional information. • to clarify and refine a model, and explanation, or an engineering problem. (NGSS Appendix F p. 51)

POINTS FOR CONSIDERATION:

- The purpose of Activity 1.1 is to engage students and encourage them to discuss their initial ideas.
- Students may want to get a "correct answer" rather than build their own explanation or models.
- **Note:** Throughout this introductory activity, students are *not* expected to provide correct responses, and their responses should *not* be corrected at this point in time. Instead, let them know that they will be working to figure out these ideas over the next several days.

PREPARATION

Class Time: 45 min.

Materials

- Van de Graaff generator and grounding wand
- balloon
- wig
- aluminum pie pans
- magnets

Activity Setup

- Set-up and test the Van de Graaff generator and demos.

SAFETY ISSUES

Do not let students with electrical medical equipment near the Van de Graaff generator. In particular, a Van de Graaff generator may be harmful to people with pacemakers or those dependent on other electrical medical equipment (cochlear implants, etc.). A Van de Graaff generator will only be hazardous if correct procedures are not followed. Do not let students use it unsupervised. See additional safety issues in the Appendix.

IN CLASS READING

Reading for Activity 1.1: Scientific Models

Activity 1.1 - Teacher Preparation

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Stickiness and flyaways
    a. Introduce curriculum and driving question for Unit 1
    b. Students brainstorm about images and what makes clothes stick together
    c. Discussion of students' ideas - NOTE: this should take a while! -- Ask students to elaborate and explain their ideas. Ask for a variety of ideas from students. As students share their ideas, demonstrate using balloons, magnets, wig, and Van de Graaff generator as appropriate.
2. Pie pan prediction
3. Van de Graaff pie pan demo
    a. Initial diagram of pie pan and VDG
    b. Discussion of students' diagrams
        i. Introduce scientific modeling
4. Revising your model
    a. Students' revised models
    b. Discuss students' revised models
    c. In-class reading

Activity 1.1 (Student materials) *What are some examples of things that stick together and things that don't?*

Introducing the Unit
This curriculum is organized around driving questions that provide context and motivation. You will be using a driving question board (DQ board) to organize information related to answering these questions gathered throughout the unit. Relevant information, includes additional questions students raise during discussions, key pieces of evidence, and explanations or models that students have agreed on.

The curriculum is organized into three units. Each unit is composed of multiple investigations, which are further broken down into activities. An activity generally runs one or two days. However, some activities, such as when students design their own scientific investigations, may take a bit longer. Each unit has an overarching driving question. The titles for all the investigations and most of the activities are also written as questions. These are sub-driving questions aimed at building toward the larger question. (See Appendix for more information on driving questions and using a driving question board.)

The driving question for all of Unit 1 is, *Why do some clothes stick together when they come out of the dryer?*

Discuss the nature of science, introduce this question, and add it to the class driving question board. (See Appendix for guidance on leading discussions.)

Possible questions:

- *How many of you do your own laundry?*
- *Do any of you fold laundry in your house?*
- *Have you ever found a sock stuck to a shirt?*
- *Have you ever noticed, if you pull them apart, what do you hear?*
- *What do you see?*
- *Have you ever wondered why?*

Science is about making observations, asking questions, and looking for patterns to try to develop answers to those questions. A sock sticking to a shirt when they are taken out of the dryer is an interesting observation that we could ask scientific questions about.

Page title:

Stickiness

Hair standing on end
Credit: Ken Bosma
License: CC BY 2.0
Image source: http://flic.kr/p/5keFrC

Styrofoam packing peanuts sticking to cat
Credit: Brian Del Vecchio
License: CC BY-NC-SA 2.0
Image source: http://flic.kr/p/8MsB6

After removing clothes from a dryer, you might find a sock stuck to some jeans. When you pull your hat off on a dry winter day, the hairs on your head may stick out in all directions.

1. What causes these things to happen? Brainstorm with your partner and enter your ideas below.

Note: Each question includes an answer box like the one shown below. These boxes are intended to provide you with some support to both respond to students' questions and ideas during class and to evaluate students' work.
In some boxes you will see a section titled "**Supplemental content**" this portion is intended to provide you with additional background knowledge to help with making decisions about how to respond to students. Students are *NOT* expected to master the ideas in the **Supplemental content** section.
The "**Student responses**" portion provides some information about what to expect and look for in students answer given the context and when the question is asked in the curriculum. You will also see some sample responses in a bulleted list. These indicate the types of things students might say. Under some of the sample responses you may also see some italicized text; this text provides some suggestions about how you might respond to students if they share a similar idea.

Student responses: The questions in this first activity are provided to elicit students' ideas. Students' answers will vary. It is good to review and discuss these answers, but do not evaluate them. At this point, students do not have enough evidence to decide if some answers are better than others.

- General statements, like "Static"
  - *Do not evaluate these responses, but you could ask students to elaborate or explain what they mean.*
- Magnetism
  - *Students may also mix up or conflate static interactions and magnetic interactions. At this point, you do not need to correct these ideas.*
- Students may also invent fantastical causes such as, "Magic".
  - *Even though this may seem like a thoughtless answer from the student, if you treat it as a serious answer you are setting the tone in your class that you care about students' ideas and that all ideas are welcome and will be taken seriously.*
  - *Again, don't evaluate these ideas, but you could ask students to explain - where did the magic come from?*
- Students may also describe what they see rather than explain it, "The kid went down the slide and his hair stood up."
  - *Again, you could ask for more information - why would the slide make his hair stand up? But do not evaluate these ideas.*

2. What questions do you have about clothes sticking together and hair standing on end?

Student responses: As before, students have not gathered enough evidence to evaluate the questions, but you could push students to be more specific.

- Students may have vague questions, like "What makes the clothes stick together?"
- Students may also include some of the questions you asked them about their responses to the previous question.

Note on Discussions

Discussions play an important role throughout this curriculum. In order to get students to share ideas and engage in lively discussions, it is important to set a tone that all ideas are important. The following types of questions can be used throughout all these discussions to encourage a variety of students to share their thoughts.

Questions to support building classroom community:

- *Does anyone have a different idea?*
- *Does anyone have a similar idea?*
- *Do you agree or disagree with that idea? Explain.*
- *What questions could we ask or investigate to sort out these ideas?*

Introducing the Lesson

An important aspect of this first activity is to elicit students' ideas so that the students have to express their thinking, get ideas about what others are thinking, and so you have a sense of where the class is. Therefore, this first activity will be mainly driven by discussions. See the Appendix for additional resources for leading discussions. Here, you will get some guidance as well, but the nature of the discussion will also depend on the ideas students share, so treat this section as flexible.

Have students share their ideas about the mechanism that causes things to stick together or push apart from each other.

Possible questions:

- *What causes objects to come together? What keeps them together?*
- *What questions do you have about this scenario?*
- *Does the composition/material of the objects matter? What is similar about the materials that stick together or repel each other?*

As students respond, avoid evaluating their ideas at this time. Simply paraphrase what the student said, ask questions to push the student to a deeper response (probing questions) and ask for ideas from other students. For example, a student may say that it is because of "static", the following questions could be used as follow-up to this response.

Potential probing questions:

- *So you said you think think the clothes stick together because of static. I've heard that word before, but it is not always clear what it means, what do you mean when you say static?*
- *Has anyone else heard the word static before? Could anyone add to our definition of static? Does anyone have a different idea of what static means?*
- *Does the the clothing always have static or does something happen to make it that way?*
- *Why don't the clothing always stick together? OR What happens? Anyone have a different idea about what makes them static?*
- *Can you think of other examples of things that are static? How are those related to our example with clothes?*

Similar follow-up questions could be used if students use other terms such as "charged", "magnetic", "positive", "negative", "attract", "repel", etc.

Ask students for examples of things that stick together or push away from each other.

Possible questions:

- *Can you think of additional examples where objects behaved similarly?*

Note: Students may provide examples involving other forces that act at a distance such as gravity and magnetism. If this is the case, include them on the list. Later they can come back to the list and identify phenomena that involve electric charge.

Demos

The following demonstrations can be done as students bring up appropriate ideas. Students may bring up some of these or similar examples during the discussion, if so either have the student demonstrate or have the student walk you through what to do.

Balloon

Blow up a balloon and hold it near the wall - it will fall. Rub the balloon with fur, your hair, or some clothing and hold it up to the wall again - it should stick. You could also try it with different rubbing materials to compare the outcomes.

If students mention what happens when a balloon is rubbed in hair, blow up and rub it in your hair (works best with fine hair with no products on it) and watch your hair stick to the balloon as you slowly pull the balloon away.

Magnets

If students mention magnets as an example of things that stick together, hand the student some magnets to demonstrate. Turn the magnets around to get them to repel as well. Are the observations of things sticking and pushing away related?

Hair

Students may mention different observations they've made of their hair standing up (for example, after pulling off a knit cap in winter). If they mention this, it is a great opportunity to introduce the Van de Graaff generator by placing a wig on top of the generator and turning it on. You could also place both hands on the generator and have a student volunteer turn it on so your hair stands up (again works best with finer hair without product). SAFETY NOTE: Make sure the Van de Graaff generator is turned off and discharged before removing hands.

Sparks

Whenever you use the Van de Graaff generator you must discharge it after you turn it off. Ask kids if the other examples that were discussed are also related to sparks. They may have the experience of pulling of a sweater or blanket in the dark and seeing sparks.

Note

If students ask about the Van de Graaff describe what happens when the Van de Graaff is turned on: A belt in the stem starts running, combs at the top rubbed against the belt as it runs, and then the dome sits on top of the combs. See Appendix for a more detailed explanation of how Van de Graaffs work. However, don't tell students that the Van de Graaff builds a lot of static charge.

Discussion:
After each phenomenon, pause for students to share their ideas.

Note: the goal of the discussion should be to get a variety of ideas from students, not to focus on "correct" ideas. See appendix for additional suggestions and tips for leading discussions.

Potential discussion questions:
Sparks:

- *When have you seen or made sparks? (examples: lightning, shock from a metal doorknob)*
- *What do you think causes sparks to occur?*
- *Do these phenomena have anything in common?*
- *What causes the big spark to shoot off from the Van de Graaff generator?*

Questions to support building classroom community:

- *Does anyone have a different idea?*
- *Does anyone have a similar idea?*
- *Do you agree or disagree with that idea? Explain.*
- *What questions could we ask or investigate to sort out these ideas?*

Throughout these discussions, continue to avoid using technical or scientific terms and ask follow up questions if students use these terms.

Balloon sticking to wall
Possible questions:

- *Have students share their ideas about what made the balloon stick to the wall.*
- *Why wouldn't it stick to the wall without rubbing it with material first? What's different about the balloon after it's been rubbed?*
- *Can you think about other examples of objects sticking together like this?*

Wig on VDG
Possible questions:

- *What do you think makes the hair stick out after the Van de Graaff generator was turned on?*
- *What is different about the hair before and after the Van de Graaff generator is turned on?*
- *What does the Van de Graaff generator do?*
- *What do these phenomena have in common?*
- *What questions do you have about these phenomena?*

Note: Save students' questions and consensus ideas about these phenomena to put on the driving question board.

Page title:

Pie pan prediction

Safety Guide
Van de Graaff generators can be harmful, especially for people with medical implants such as pacemakers or cochlear implants. If you have one of these, ***DO NOT*** *touch the Van de Graaff generator! Be careful, the Van de Graaff generator can give you a painful and potentially hazardous shock.*

Note: The aluminum pie pan demonstration is used to elicit students' initial models for electrostatic interactions.

Put the pie pans on the top of the generator and ask students to make a prediction about what will happen when the generator is turned on.

3. There are aluminum pans sitting on top of the Van de Graaff generator. Predict what will happen to the pans when your teacher turns on the Van de Graaff generator.

Student responses: Students will come up with a variety of predictions. Students do not have evidence to evaluate any of these ideas yet. Do not evaluate students' responses, just encourage a range of ideas. One student may even record multiple possible predictions.

- the pie pans will float
- fall off,
- it will create sparks,
- the pie pans will get smashed down

Page title:

Van de Graaff pie pan demo

After the demonstration:
Discuss the pie pan demo and discuss how it relates to the examples discussed earlier.
Possible questions:

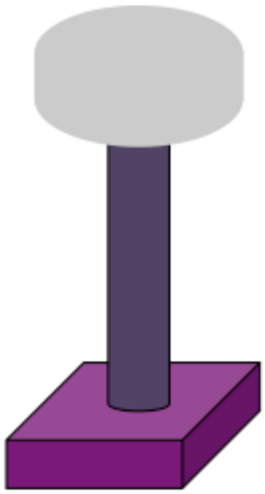
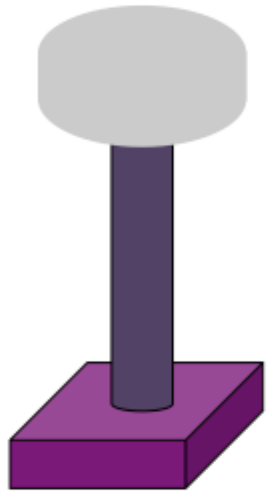
- *Note: It might be helpful to quickly review the examples that were brought up in earlier discussions first.*
- *Could our observations of the pie pans be caused by the same things that make hair fly away or thing stick together?*
- *How is it similar? How is it different?*
- *Does anyone have a different idea?*

Note: If students share that they think the pie pans are related to magnets instead of static, try using the magnets to see if you can recreate the pie pans flying apart.

4. [drawing prompt] Now that you've seen what happens to the pie pans after the Van de Graaff generator is turned on, make two drawings to show what caused the pie pans to behave the way they did.

[text prompt] Label your drawings and explain what is happening at each step so that anyone can understand your drawings.

If you want to see the demonstration again, watch the following video: Pie pan demonstration.

Before the Van de Graaff generator was turned on	After the Van de Graaff generator was turned on
	

Student responses: As their first modeling attempt, students generally draw a representation of what they observed. Students may or may not include some causal mechanisms, for example, students may try to include a representation of static or electricity. See the discussion box below for suggestions for discussing the initial drawings.

Discussion
Display some sample drawings anonymously. (See Appendix for tips on displaying student work for discussions.) Ask students to compare the drawings.
Possible questions:

- *What do you notice about the diagrams? How are they similar/different?*
- *Did anyone notice something different?*
- *Does anyone have questions about any of the models you see?*

Introduce scientific models and discuss how the drawings display important aspects of scientific models. You could introduce this topic by informing students that their drawings are their initial scientific models.

In your introduction, be sure to include the following:

- Scientists try to explain and make predictions about phenomena; one way they do this is by using models.
- Models must be connected to a phenomenon—that is, models must be useful for explaining observations or making predictions about a phenomenon.
- Building a model should always start with a question that the model will answer.
- A model is not just a picture of what happens; it shows what caused the outcome. Models provide a causal mechanism—a chain of events that leads to a particular outcome.

Refer to students' models to highlight how they connect to the phenomenon and how they provide a causal mechanism.

Possible questions:

- *How do these models relate to the phenomenon we observed?*
- *How do these models use what we learned to provide a mechanism for what caused the phenomenon to occur?*
- *What could be added to these models to make them stronger scientific models?*
- *Does anyone have a different idea? Does anyone have new questions about these models or our observations?*

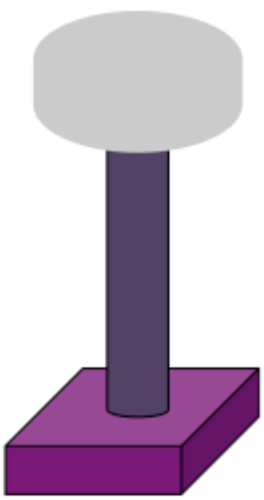
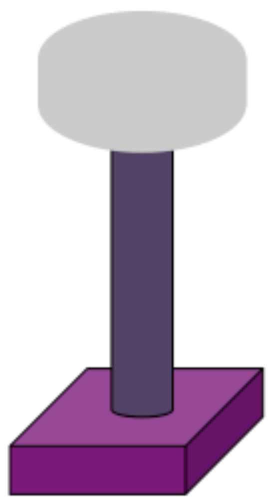
Record students' questions that are particularly relevant. If any are similar or related to future investigation-level or activity-level driving questions, make sure to save those. These can be posted to the DQ board. You will return to the DQ board as the class continues to collect evidence and answer questions.

Page title:

Revising your model

5. [drawing prompt] After your class has discussed scientific models and reviewed some of the drawings from your class, revise your model of the Van de Graaff generator and the pie pans. Be sure to include a mechanism that could explain what caused the pie pans to fly off the Van de Graaff generator.

[text prompt] Label your drawings and explain what is happening at each step so that anyone can understand your drawings.

Before the Van de Graaff generator was turned on	After the Van de Graaff generator was turned on
	

Sample responses: At this point, students should be attempting to include some causes in their diagram. Their answers will likely be incomplete and vague, but it should not be just a picture of what they observed. If students just draw the pie pans, ask them to think about what happened that caused the pie pans to fly off and how could they represent that? The addition may be as simple as adding a plug to show that plugging the VDG in caused the pie pans to fly off.

Note: The DQ board is a place to record students' questions about the topic and track progress toward answering the unit-level driving question. The class will come back to the DQ board after collecting more evidence as students are exposed to more phenomena and simulations about electric interactions. (See Appendix for more information about driving questions.)

Revisiting the Driving Question:

- Introduce the driving question for this investigation, *Why do some things stick together and other things don't?* and the driving question board (DQ board).
- Post some of the ideas/models that students used to explain the demonstrations. This will represent the initial set of class models, which they will modify and add to throughout the unit.
- Post some of the relevant questions students shared about the demonstrated phenomena.
- Ask if they have any other questions related to the driving question or phenomena they observed.

In Class reading: Reading for Activity 1.1
Scientific Models

Discussion:

- Students need support for reading scientific text. Use this first reading as an in-class active reading task to introduce students to scientific reading.
-
- Habits of good readers:
- Make connections between the reading, class activities, and experiences from their lives
- Stop to analyze any diagrams, figures, and tables as they are referenced in the reading
- Note any questions or thoughts they have while reading
- Note and reflect on the purpose of the reading - in formal text this often requires paying attention to headings

To introduce students to these habits, have them read sections quietly (give students a specific amount of time per section) or randomly call on students to read aloud (mix it up, don't let one kid read for too long, and hold all students accountable for following along). Let students know ahead of time that you will be stopping them as they are reading to discuss the ideas.

Possible questions:

- *How does that idea relate to what we talked about in class?*
- *Notice, it just referenced a figure. Where is that figure? Let's look at it before continuing, what do you notice in the figure? How does that connect to what we were reading about? How does that connect to what we did in class?*
- *What was the main point of that section?*
- *What was the main point of the paper?*

Making notations in the margins of a text, sometimes called "Talking to the Text" is a powerful way to support reading development. As you go through the reading as a class, when students identify an important idea have them underline or circle that idea and add a note in the margin to summarize, highlight, make a connection, or ask a question about the quote. (This becomes a great way to check students' reading assignments - you can require that they make a certain number of notations per page, and can quickly see if students did in fact read the whole assignment).

For more information on reading strategies, you can search: "talking to the text" or "reading apprenticeships"

Activity 1.2 What are some patterns in how things stick together or push apart?

SUMMARY

Students will use charged pieces of tape and a computer simulation representing the interaction between charged spheres to identify patterns in how electrically charged objects interact with each other. Students can use these patterns to help them predict whether two charged objects will stick together or repel each other. In the next activity, students will explore the patterns in the interactions between charged objects and uncharged objects.

LEARNING GOAL

Students will collect and interpret data to identify patterns in the way that charged objects interact with each other.

Disciplinary core idea	Crosscutting concept	Science and engineering practice
Structures and properties of matter: The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms (NGSS Lead States, p. 94).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82).	*Planning and carrying out investigations:* Use investigations to gather evidence to support explanations or concepts. (NGSS Appendix F p. 53).

POINTS FOR CONSIDERATION

- Students may be able to state, "Opposites attract; likes repel," but they may not have an understanding of the scientific principles behind that statement.

PREPARATION

Class Time: 60 min.

Materials (for each group)

- translucent (cloudy) Scotch tape. (Clear tape does not work as well.)
- pen or pencil for labeling
- Magnets

IN CLASS READING

Reading for Activity 1.2: How Did the Pieces of Tape Interact?

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Introduction
    a. Discussion-Introducing the lesson
2. Tape
    a. Investigate tape interactions with a partner.
    b. Answering questions based on observations
    c. Class discussion
3. Simulations to help us explore and understand
    a. Discussion-simulations as models
    b. Magnet test
    c. Simulation - Patterns with pos-neg spheres
    d. Simulation - Modeling tape interactions
4. How did the pieces of tape interact?
    a. In-class reading assignment
    b. In-class reading discussion
    c. Wrap-up discussion: Concluding the lesson

Activity 1.2 (Student materials) *What are some patterns in how things stick together or push apart?*

Page title:

Introduction

In the last activity, you observed some examples of objects sticking together or pushing away from each other. How can you predict what will happen to objects? In this activity, you're going to explore how some objects interact and analyze your observations to see if there are any patterns in the way they interact.

Introducing the Lesson
Refer to the DQ board, and show the activity-level driving question: *What are some patterns in how things stick together or push apart?*

Review the discussions from Activity 1 about what might have caused the various phenomena they observed. In order to develop explanations, students will need to study these interactions more closely and try to identify patterns in how things interact.

Possible questions:

- *What were some possible causes for our observations with the Van de Graaff machine?*
- *Could there be patterns that would allow us to predict how a new object would interact with the ones we already observed?*
- *What do we need to know in order to develop more detailed explanations or make predictions?*

Remember, if students bring up science terms, be sure to ask them to explain what they mean, and see if other students have additional or different ideas.

Post representative ideas and questions to the DQ board.

Page title:

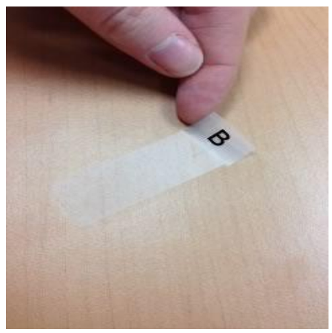
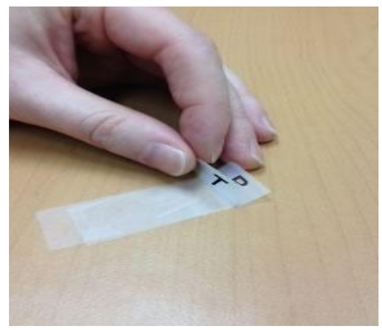
Tape

Materials

- Scotch tape
- pen or pencil for labeling

Investigate

Each person in your group should follow the steps below.

		
1. Get a strip of tape that is 1.5 to 2 inches long. Fold over one end of the tape as shown in the figure above. This will give you a non-sticky handle to hold the tape with.	2. Stick this piece of tape to the desk, and label the handle “B,” for *bottom.*	3. Get a second strip of tape that is 1.5 to 2 inches long, and fold it in the same way. Place it directly on top of the first piece of tape, and label the handle “T,” for *top.*
		

4. Using the handles, lift both pieces of tape off the desk at the same time. Then touch the entire length of the strip on both sides with your fingers several times.	5. Pull the pieces of tape apart, making sure to not touch the tape anywhere except on the non-sticky handles you made.	6. Experiment with your partner to see how the pieces of tape interact with each other when you bring two of them close together in different combinations. **Tip:** *Try not to let the pieces of tape touch each other. If they do touch a little bit, it might be okay but it might change their behavior. Try to avoid having the pieces of tape touch if possible.*

This link is a video clip that illustrates the procedure: How to do the tape activity.

1. **Write your observations of what happens when you bring the pieces of tape close together in *each* combination (T-T, B-B, and B-T).**

Supplemental content: Two T pieces of tape push each other apart. The T tape and B tape pull toward each other. Two B tapes push each other apart.

Clarification - students may not observe these interactions, they should record what they observe. If their observations are inconsistent, they should check their procedures and record the most consistent observations.

Student Responses:

- The two pieces of tape labeled T moved away from each other
- The T tape and the B tape moved toward each other.
- Nothing happened
  - *Encourage students to try the activity again. Remind them that the pieces of tape should not touch each other if possible because that might affect their behavior.*

2. Based on your observations, what patterns can you identify when two pieces of tape interact?

Supplemental content: The same types of tape repel each other, but different types of tape attract each other.

Clarification - students do not need to use the technical terms ("attract", "repel", etc.)

Student responses: Students should have a general description of the patterns, not their specific observations. Students should have come to a consensus as a class on the pattern.

- Similar tapes repel opposite tapes attract
- T tapes repel each other, B tapes repel, T & B attract
  - *Push student to generalize*
- There was no pattern
  - *Encourage student to analyze the class data and look for patterns from across the class*

Discussion

Review students' results by making a table on the board where students can record their observations. There will be three columns: T-T, B-B, and T-B. One student from each pair can record their results in the box, or tables can discuss and record their combined results. Use results to spark discussion about patterns in the data as listed below. If there are inconsistencies, prompt students to repeat the experiment.

- After students share their data, help them identify patterns. Discuss why those patterns occur and how those patterns might be used to make predictions about interactions between other objects.
- Students should recognize the following patterns: Two of the same type of tape (T-T or B-B) repel each other, and two different types of tape (B-T) attract each other.

Possible questions;

- *What did you observe when the tapes interacted?*
- *If we look at the class data, what patterns can we find?*
- *How could we generalize our observations?*

Note: Students often have difficulty identifying patterns from data. Help them notice the difference between observation (what they actually see) and patterns (generalization about what they see).

Page title:

Simulations help us explore and understand

Discussion

The goal of this discussion is to help students understand why using simulations is helpful when exploring phenomena. Sometimes, what causes an outcome cannot be seen, but simulations can show such invisible components, as well as components that are visible.

Possible questions:

- *We can see someone pushing a door open. But we can't see what causes the tape to push apart or pull together. What makes the pieces of tape repel or attract each other? (See Note below.)*
- *Remember to ask follow-up questions about what students mean by the terms they use.*

Review what a model is and discuss different types of models. Remind students that models can be used to visualize things that cannot be seen. Then explain that simulations are dynamic, interactive models that allow possible causes to be tested.

3. Use the magnets to test your tape to see if the tape behaves like a magnet. Can you get the magnet and the tape to interact in all the same ways as the two pieces of tape? Describe any similarities or differences in behavior.

Supplemental content: In terms of electrical charge, the magnet is a neutral object (it has equal numbers of protons (+) and electrons (-). Therefore, the magnet and either the positively charged or negatively charged tape will attract. The tape is not magnetic and the magnet is not electrically charged, so they will never repel.

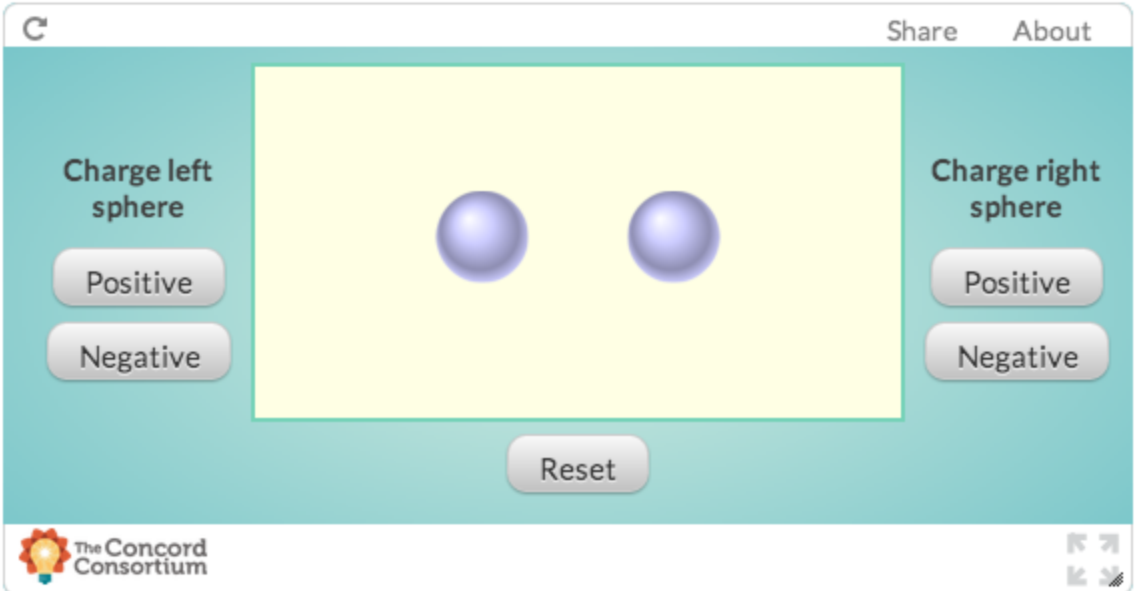
Clarification: Students should only be recording their observation, they do not need to explain why the tape and magnet attract or do not repel.

Student responses:

- No, the tape and magnets never repel.
- Yes, the tape bends towards the magnets too.
  - *Challenge students: ask them if they were able to get the tape and magnet to repel each other. Are there any combinations of magnet and tape that lead to repulsion?*

What causes the T and B pieces of tape to move toward or away from each other?

Use the simulation to identify patterns in how two charged objects interact. Think about how these patterns relate to the patterns you observed with the tape.



Simulation link: http://lab.concord.org/interactives.html#interactives/interactions/chargeballs.json

4. What patterns do you notice in the way the spheres interact with each other?

Supplemental content: If the two spheres have the same charge, they move away from each other and end up far apart (likes repel). If they have different charges, they move toward each other (opposites attract). Students may notice that when one sphere is charged and the other is not, they move together slowly. This will be explored in later activities.

Clarification: Students are only listing the patterns that they notice while conducting the simulation. It is ok if they do not notice everything listed here.

Student responses:

- When the spheres have the same charge, they move far apart.
- When the spheres have different charges, they move together.
- When one has a charge, and one doesn't they slowly move together
    - *This phenomenon will be explored in later activities. It is ok if students do not notice this at this time.*

5. Use your observations from the tape activity, the magnet tests, and the patterns you identified from the simulation to explain what may have caused the pieces of tape to interact. Support your explanation using the results of the magnet test and your observations of the different conditions in the simulation.

Supplemental content: The charged objects in the simulation attracted when they had different charges and repelled when they were of the same charge. This is the same pattern as observed with the top and bottom tape. The tape could be charged: one positive and one negative. The magnets and tapes never repelled showing the tapes are not magnetic. The charged objects in the simulation had all the same interactions as the charged pieces of tape.

Clarification - Students should use the patterns in the simulation and the patterns in their observations to connect the idea of charge and the interactions with the pieces of tape. They may focus more on the simulation or magnets. Students do not need to explain how the tape got charged, the interaction between the tape and the magnet, or which tape has which charge.

Student Responses:

- The spheres that had the same charge moved apart just like the pieces of tape that were labeled the same. The pieces of tape labeled T must have had the same charge, and the pieces of tape labeled B must have had the same charge. This would make sense because when a T and B tape were brought close together, they moved together like the spheres that had opposite charges. The magnets did not interact with the tape, so magnetism cannot be the cause.

IMPORTANT NOTE: These ideas are reviewed through the class discussion described below. Through the discussion, students may add to or revise their answer to this question. This is part of the learning process and we expect students to update their answers as they develop their ideas through discussions with partners and the class. At the end of the discussion, you may even want to instruct students to return to this question and revise their answer.

Discussion

Review the simulation and use it to introduce the modeling scaffolds: components, relationships between components, and connection to phenomenon. (See Appendix for additional information on modeling scaffolds.) When introducing these aspects of scientific models, be sure to discuss what models are and how scientists use them.

Scientists try to explain observations or phenomena. Models are a very useful tool that scientists use to communicate and show underlying causes. Models are useful for explaining and making predictions about phenomena.

When using or developing models, there are three important aspects of modeling to keep in mind:

1) *Components* - Models are simplifications of phenomena, so they do not show everything. However, they must include key components. Some components may be parts of the phenomena that can be observed, but some may be invisible underlying causes.

Possible questions:

- *What components are shown in this simulation?*
- *What else do you see?*
  Note: students may make "obvious" statements such as "yellow background", "words". These observations are true and should be honored just like observations that focus on the spheres - students are still figuring out which components they need to pay attention to.
- *If I change component a, how would that affect component b?*

2) *Relationships* - How are the components related to each other? How do they interact with each other?

Possible question:

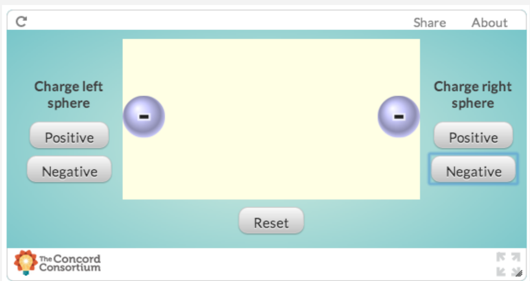
- *Using the answer to the previous question to build the relationship: How does component a relate to component b?*
- *What other relationships can we see in this simulation?*

3) *Connection to the phenomenon* - The relationships between the components should help you explain observations or make predictions.

Possible question:

- *How does this simulation relate to our observations of the pieces of tape?*
- *If the pieces of tape had positive and negative charges, could that explain our observations?*
- *Which explains our observations better, if the tape is magnetic or if the tape is charged? Were you able to get all the interactions between the magnets and the tape?*

6. Adjust the charges on the spheres to make them behave like the *two T strips* of tape did when they were brought close together. Then take a snapshot of the simulation and indicate how the spheres interact.



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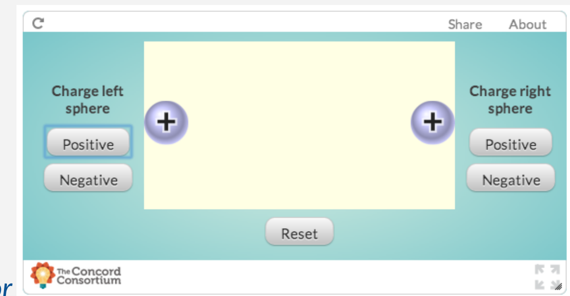
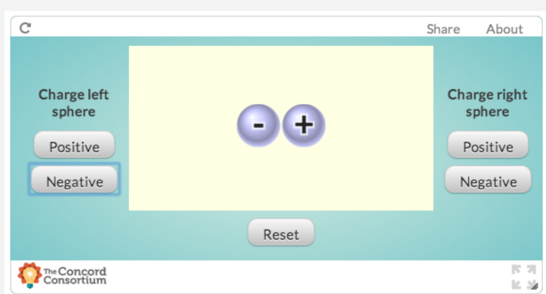


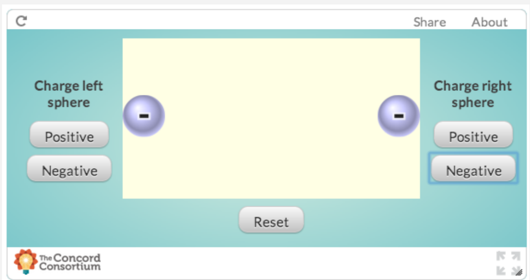
(both negative) *(both positive)*

7. Now adjust the charges on the spheres to make them behave like the *T and B tape strips* did when they were brought close together. Then take a snapshot of the simulation and indicate how the spheres interact.



(One ball should be positive, and the other should be negative.)

8. Finally, adjust the charges on the spheres to make them behave like the *two B tape strips* did when they were brought close together, and take a snapshot. Don't forget to include the interaction between them.



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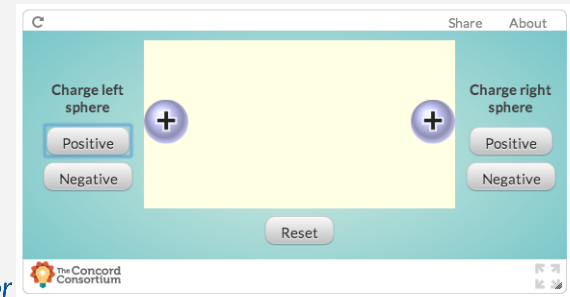


(both negative) *(both positive)*

9. A simulation is a type of model, and a model must connect to a phenomenon. How does this simulation relate to the phenomenon you observed with the T and B tape strips?

Student response:

- The simulation shows that when objects are charged, they move together or away from each other. The objects in the simulation move in patterns that are similar to the strips of tape.
  - *Students may not notice the interactions between charged and uncharged objects at this time because they are subtle. Do not point it out to students, but if they do notice those interactions, encourage them to record those observations to return to later.*

Page title:

How did the pieces of tape interact?

In class reading for Activity 1.2

How Did the Pieces of Tape Interact?

Note: This is a good chance to model reading skills for students (stopping to ask questions and make connections, referring to the figures as you are reading, etc.). You may also want to have students underline important concepts and circle words that they need more information to understand. Use some of the reading strategies that worked well in the last activity, and alter reading strategies to meet the needs of the students.

To keep faster readers from finishing long before slower readers, tell students how much time you are giving them to read specific portions of the text and then stop to discuss that portion. Alternatively, you could also read aloud together; however, if you read aloud, be sure to stop frequently to discuss and to regularly change who is reading.

Possible questions:

- *What was the main point of the section (what did you underline while reading)? Does anyone think there are different important ideas?*
- *What questions do you have about the section? Are there words that we need more information about? Does anyone else know what that word means?*
- *What ideas from class or your life can you connect to the reading?*

In particular, be sure to discuss the figures: ask students what they notice and how it relates to both the reading, and their observations with the tape. Students will be asked to represent forces in some of their models. Make sure to point out how forces are represented here, and have students explain and interpret how the relationships are represented.

Possible questions:

- *What is being represented in this figure?*
- *How is the force shown in the figure?*

Concluding the Lesson
Return to the activity-level driving question: *What are some patterns in how things stick together or push apart?*

Possible questions:
How can you explain other phenomena using your patterns? (Return to some of the phenomena from Activity 1.1.)
Can you think of any new phenomena that might also be explained using this model?

Return to the investigation-level driving question: *Why do some things stick together and other things don't?*

Possible questions:

- *Discuss how patterns in the way charged objects interact help answer the driving question.*
- *What other questions must be answered before we can answer the driving question?*

Activity 1.3 What effect do charged objects have on uncharged objects?

SUMMARY

In the last activity, students analyzed interactions between charged objects. In this activity, students will learn that most objects are inherently neutral, and they will analyze interactions between neutral and charged objects. The activity will primarily serve to get students thinking about how neutral objects interact with charged objects, but it will not necessarily help them understand the underlying mechanisms. Later in this investigation, students will collect evidence to support the idea that neutral objects are attracted to both positively and negatively charged objects. This activity will help students develop a more nuanced and detailed answer to the driving question for the unit: *Why do some things stick together while other things don't?*

LEARNING GOALS

- Students will use collected evidence to determine whether an object is neutral or charged.
  - Clarification: At this point, students' definition of *neutral* will just be "uncharged" or "no charge."

Disciplinary core idea	Crosscutting concept	Science and engineering practice
PS1.A Structure and properties of matter: The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms (NGSS Lead States, p. 94).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82)	*Analyzing and interpreting data* Use tools, technologies and/or models to generate and analyze data in order to make valid and reliable scientific claims (NGSS Appendix F p. 54).

- Students will predict what will happen when a neutral object is close to another object.
  - Clarification: Neutral objects and charged objects attract each other, but two neutral objects do not seem to attract or repel each other. At this point, the type of charge is not specified.

Disciplinary core idea	Crosscutting concept	Science and engineering practice

PS2.B Types of interactions: Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects (NGSS Lead States, p. 95).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82)	*Developing and using models :* Use models to predict and support explanations of relationships between systems or between components of a system (NGSS Appendix F p. 52).

- Students will apply patterns observed in activities and simulations to develop a model for how charged and uncharged objects interact with each other.

Disciplinary core idea	**Crosscutting concept**	**Science and engineering practice**
PS1.A Structure and properties of matter: The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms (NGSS Lead States, p. 94).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82)	*Developing and using models:* Develop, revise and use models to predict and support explanations of relationships between systems or between components of a system (NGSS Appendix F p. 52).

POINTS FOR CONSIDERATION

- Students may believe that if two objects attract or repel each other, they must be charged. If students believe this, they will likely also believe that attraction or repulsion will not be observed when interactions involve neutral objects with charged objects.
- Students may not know that most objects are inherently neutral. When they observe the attraction between charged and neutral objects, students often assume that the neutral object is charged. This is acceptable for now. In later investigations, as students learn about atomic structure, further evidence will be provided.
- Students often have difficulty understanding the relationship between models and the phenomena they represent. They may believe:
    - that models must look exactly like the target phenomenon, but just larger or smaller.
    - that there is only one type of model, neglecting that there are many types, including mathematical, computational, and symbolic models.
    - that there can only be one model for any given phenomenon. In this case, the models that apply to the tape and the spheres in the computer simulation can be applied to understanding how the hair repelled and stood on end when the Van de Graaff generator was turned on.

Activity 1.3 - Teacher Preparation

PREPARATION

Class Time: 60min.

- Materials (for each pair)
    - fur pad
    - dry, empty plastic bottle with cap
    - small pieces of paper (or tissue)
    - isopropanol wipes

Activity Setup

- Have students work in pairs for this activity.
- Construct a materials kit for each pair.

Note: Modeling is important to this lesson. To support students in developing an understanding of scientific models, it is recommended to do the reading “Aspects of scientific models” in class as listed in the teacher materials.

IN CLASS READING

Reading 1 for Activity 1.3: Aspects of Scientific Models

HOMEWORK

Reading 2 for Activity 1.3: Electric Interactions in Daily Life

Activity 1.3 - Teacher Preparation

BASIC OUTLINE OF ACTIVITY

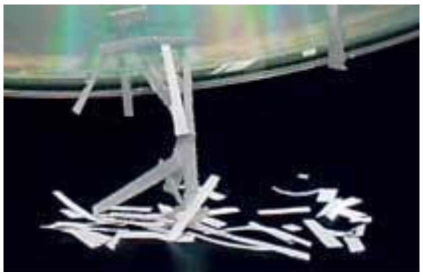
Use this space to make notes to prepare for your lesson

1. Introduction
    a. Discussion-Introducing the lesson
    b. Questions: Charged and neutral objects
2. Water bottle and paper
    a. Investigating interactions between charged water bottles and uncharged paper bits.
    b. Discussion - how are students identifying charged and neutral objects?
3. Water bottle and hand
    a. Collecting data on interactions between the water bottle and a hand
    b. Questions based on student observations
    c. Class discussion
4. Developing a model
    a. In-class reading and discussion
    b. Developing models of interactions between charged objects
    c. Developing models of interactions between charged and uncharged objects
    d. In class discussion of student models using the projector.

Activity 1.3 (Student Materials) *What effect do charged objects have on uncharged objects?*

Page title:

Introduction



DQ

Introducing the Lesson
Ask students to recall how charged objects interact with other charged objects (the same charges repel; opposite charges attract).

Possible questions:

- *Based on these behaviors, do you think all objects in the universe have an electric charge? If so, does that mean every object must interact with all other objects through electric forces? If not, how do objects interact? Or do they interact at all?*
- *What are some examples in which objects do not appear to interact with other objects?*
- *How do you know whether an object is charged or not?*

Refer to the driving question board and introduce the activity-level driving question: *What effect do charged objects have on uncharged objects?*

1. What do you think will happen if two uncharged (neutral) objects are brought close together?

A. They will attract each other.
B. They will repel each other.
C. Nothing. They will not interact.
D. Not sure.

2. What do you think will happen if a charged object is brought close to a neutral object?

A. They will attract each other.
B. They will repel each other.
C. Nothing. They will not interact.
D. It depends on the type of charge (+) or (-).
E. Not sure.

Student responses: These questions are asking for the students to make a prediction. Students' answers will vary, and they do not yet have enough evidence to select a correct answer. Refrain from evaluating their work here.

Page title:

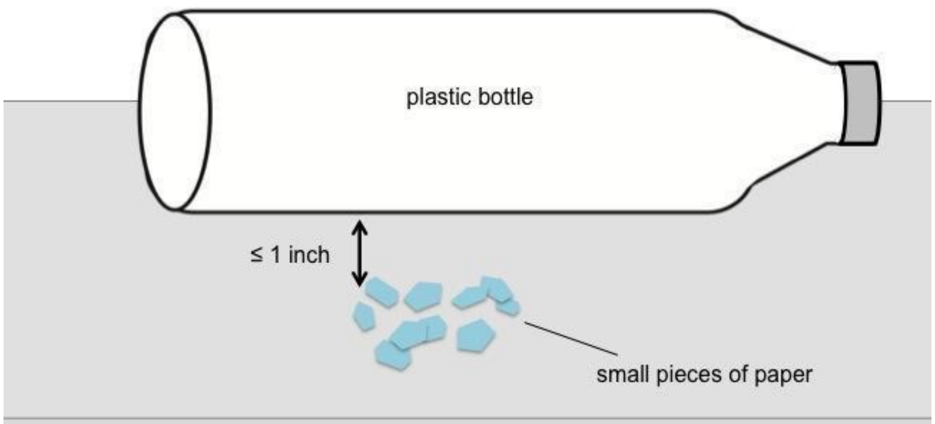
Investigating the interactions between a plastic bottle and paper

Materials

- fur pad
- dry, empty plastic bottle with cap
- small pieces of paper (or tissue)
- isopropanol wipes

Investigate

Part 1: Have one partner hold the empty plastic bottle by its cap, rub the bottle with an alcohol wipe, and let the bottle dry. Still holding the bottle by its cap, bring the bottle above and very close to the bits of paper, but don't touch them with the bottle.



Bring bottle ≤ 1 inch from the pieces of paper, but don't touch the paper with the bottle.

3.Write your observations below.

Student responses: Students should not observe any interaction between the uncharged bottle and pieces of paper. Their answers to the questions in this activity should not be evaluated as they will gather evidence to support their claims in the next activity.

- There was no interaction between the water bottle and the paper.
- The pieces of paper stuck to the side of the water bottle..
    - *Tip: You could prompt the entire class to try it, trade roles, and have their partner try it to make sure observations are consistent.*

4. I think the pieces of paper are

A. charged
B. neutral (uncharged)
C. not sure

5. Explain why you chose your answer.

Student responses:

- A: Charged - all objects have charges on them, so the paper must be charged
  - *Challenge students to think about how the paper was charged.*
- B. Neutral - We didn't do anything to the paper to charge it, so it must be neutral.
- C. Not sure - All objects have charges, but the paper didn't move to the water bottle, so I am not sure.
  - *Challenge students to think about where objects get their charges from and how charges cause objects to interact with other objects.*

6. I think the plastic bottle is

A. charged
B. neutral (uncharged)
C. not sure

7. Explain why you chose your answer.

Student responses:

- A: Charged - all objects have charges on them, so the the bottle must be charged
  - *Challenge students to think about how the paper was charged.*
- B. Neutral - Nothing was done to the bottle to charge it (no rubbing). The bottle didn't attract or repel the paper.
- C. Not sure - All objects have charges, but the paper and bottle didn't attract, so I am not sure.
  - *Challenge students to think about where objects get their charges from and how charges cause objects to interact with other objects*

Part 2: Have one partner hold the empty plastic bottle by its cap, rub the bottle with an alcohol wipe, and allow the bottle to dry. Still holding the bottle by its cap, **rub the bottle with the fur.** Bring the bottle above and very close to the bits of paper, but do not touch them with the bottle.

Tip: *After you have rubbed the bottle with fur, be careful to hold the bottle only by its cap. Do not touch any other part of the bottle.*

8. Write your observations below.

Student responses:

- After rubbing the water bottle with fur, the pieces of paper were attracted to it.
- I didn't see anything happen
  - *Ask students to repeat the activity making sure that they are only touching the water bottle by its cap.*

Note: Make sure students see the pieces of paper "jump" to the bottle. If students are not getting the desired results, ask them to repeat the activity- following directions closely- to collect the necessary evidence.

9. I think the pieces of paper are

A. charged
B. neutral (uncharged)
C. not sure

10. Explain why you chose your answer.

Student responses: At this point, it is reasonable for students to select any of the three answer choices. Because they have observed interactions between charged objects in prior investigations, students may believe that the paper is charged and not neutral. It is difficult to "prove" that something is neutral, so students may not reach a consensus at this time. How neutral objects interact with charged objects is an idea that the class will have to return to over the course of the investigation.

- A. charged - The pieces of paper must be charged because they are attracted to the charged bottle.
  - *Ask students if they have additional evidence that the paper is charged*
  - *What did you do to charge the paper?*
- B. neutral (uncharged) - Objects are generally neutral. Nothing was done to the paper to charge it (no rubbing). The pieces of paper don't attract or repel each other.
  - *Ask students if they have additional evidence that the paper is neutral*
  - *What do you think "neutral" means?*
- C. not sure - Sometimes the paper behaved like it was neutral and sometimes it behaved like it was charged.
  - *Ask students to clarify what happened to the paper in each case*

11. I think the plastic bottle is

A. charged
B. neutral (uncharged)
C. not sure

12. Explain why you chose your answer.

Student responses: Objects can be charged by rubbing them with another material.

- A charged - After it was rubbed with fur, the surface of the bottle became charged.
- B Neutral - If the water bottle was neutral before, it must still be neutral
    - *What does neutral mean?*
    - *Did you notice a difference in the interaction between the water bottle and paper after you rubbed the bottle with fur?*
- C Not sure - I am not sure because it was neutral before, but it attracted the paper this time.
    - *What did we do differently this time that made the interaction between the paper and the water bottle different?*

Discussion

Because they have observed interactions between charged objects in prior investigations, students may believe that the paper is charged and not neutral. It is important for students to begin to understand the idea of neutrality so that they can see the patterns of interactions between neutral and charged objects in this activity and the next activity.

Pause and discuss how students are identifying charged and neutral objects. This is a difficult idea and difficult to prove, so students may not reach a consensus at this point. The class will have to return to this topic over the course of the investigation.

Consider reminding students that in general, most objects are neutral.

Possible questions:

- *How can you tell whether an object is charged or neutral?*
    - *Answer: No observable electric attraction or repulsion occurs between two neutral objects.*
    - *Students may not quite reach this answer now. If not, come back to the question at the end of the activity.*
- *Was anything done to the paper to charge it? What about the bottle?*

Page title:

Investigating the interactions between a plastic bottle and your hand

You just saw pieces of paper “jump” to a bottle. Now you will attempt to make a bottle roll without touching it.

Part 1: Rub the plastic bottle with an alcohol wipe. After the bottle is dry, place it on a table or counter with a smooth surface.

Bring your hand close to the side of the bottle without touching it (see picture). Observe what happens and fill in the first row of the table.

Attempting to roll a plastic bottle without touching it

Note: As mentioned previously, students should not be expected to identify the type of charge on the bottle or their hand at this point. A “yes/no” answer is sufficient.

Data Table

Experiment	Is the bottle charged?	Is your hand charged?	Observation: How did your hand and the bottle interact?
Bottle not rubbed with fur			
Bottle after rubbing with fur			

Part 2: Have one partner hold the bottle by its cap and rub the bottle with fur. Be careful not to

touch the rest of the bottle. Still holding the bottle by its cap, carefully place the bottle on its side on the smooth surface. Now bring your hand close to the side of the bottle without touching it. Observe what happens and complete the rest of the table.

Tip: *Try not to touch the bottle. If you do, you will have to start over.*

Tip: You may need to direct students to draw their hand away from the bottle as the bottle moves over the surface of the table; otherwise, the bottle may touch their hand and discharge.

13. Take a snapshot of your table when it is complete.

[text prompt] What do you think would happen if you brought your hand close to the small pieces of paper that you used previously? Explain why.

Student responses: At this point, students are using the evidence obtained from the water bottle and paper to make predictions. Do not evaluate student predictions as they will gather evidence to support/refute these ideas later.

- No attraction or repulsion would be observed. The paper and my hand are neutral.
- No attraction or repulsion will be observed. The same thing happened when I brought the bottle that hadn't been rubbed near the pieces of paper. The bottle wasn't attracted to my hand because the bottle hadn't been rubbed with fur.

14. Based on your observations, predict what will happen if any charged object is brought close to a neutral one. Include evidence from your observations.

Student responses: Students are making predictions about the interactions between charged and neutral objects based on prior observations.

- The neutral object and charged object will be attracted to each other. My neutral hand and the neutral pieces of paper were both attracted to the charged bottle.
- Nothing will happen because one of the objects does not have a charge on it.
  - *Tip: If students do not remember their observations or are confused, prompt them to retry the activity.*

Discussion

Ask students how they know whether an object is charged or neutral. If they

Click here to see the demonstration:

Page title:

Developing a model

In class reading:

Reading 1 for Activity 1.3 Aspects of Scientific Models

Note: This is a good chance to model reading skills for students (stopping to ask questions and make connections, referring to the figures as you are reading, etc.). You may also want to have students underline important concepts and circle words that they need more information to understand. Use some of the reading strategies that worked well in the last reading activity, and alter reading strategies to meet the needs of the students.

Possible questions:

- *What was the main point of the section (what did you underline while reading)? Does anyone think there are different important ideas?*
- *What questions do you have about the section? Are there words that we need more information about? Does anyone else know what that word means?*
- *What ideas from class or your life can you connect to the reading?*

Discussion of the Reading

Have students begin to describe and discuss scientific models and important aspects of models.

Possible questions:

- *Why are models used in science? What makes them useful? Do you have any other ideas?*
- *The reading identified three aspects of modeling. Why is it important to think about these aspects whenever you are using a model or creating your own model?*
- *How do we evaluate models?*

You will create your own model to explain your observations of the T and B pieces of tape, and the interactions between the water bottle and the paper or your hand. As you develop your models, be sure to think of the three aspects of modeling:

- Components
- Relationships
- Connection to the phenomenon

15. Start by identifying the important components to include in your model of the tape strips.

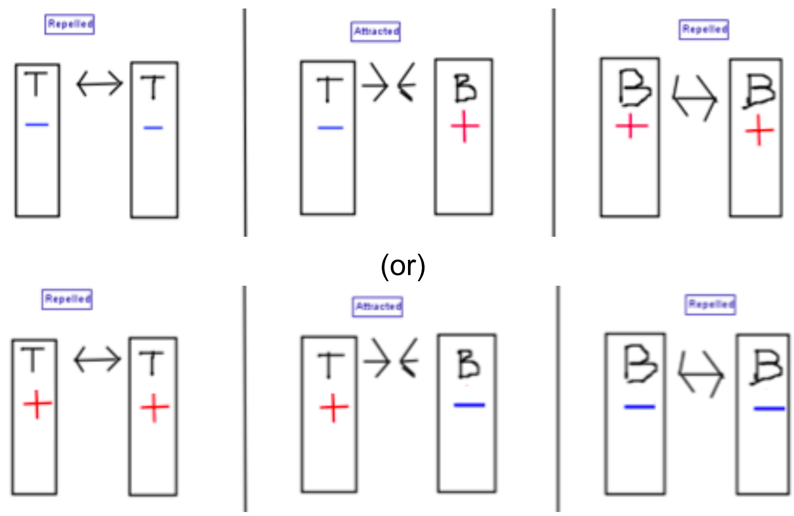
Student responses: Students should list all the components needed for their model.

- Tape strips, charged particles, neutral particles.

16. [draw prompt] What happened when you brought the different combinations of tape near each other? Draw a model to show what you think is happening. Your illustrations should show charge and force.

Two T tape strips	Two B tape strips
T tape strip and B tape strip	

Student responses: Students should include the different types of tape and indicate the interactions between the tapes. Students may represent the interactions using arrows, "motion lines", or simply drawing which way the tape bent. Note: Students do not have evidence at this point about which charge the T and B tape strips have. Therefore, some students may choose to make the T strips negative, and some may choose to make them positive. This is fine at this point. However, students should note that their two T strips have the same charge and their two B strips have the same charge, since the same kinds of tape repel each other. They also need to show that the T and B strips have a different charge, since different kinds of tape attract each other.



17. [draw prompt] **Draw a model that shows why the bottle only moves toward your hand after it has been rubbed with fur.**

[text prompt] An important relationship to include in your models is what happened when the objects interacted with each other. How did you illustrate this relationship in your model?

Bottle - Hand before rubbing with fur	Bottle - Hand after rubbing with fur

Student responses (models): Students do not have evidence at this point about which charge was on the water bottle, just as in the tape strip model. Some students may choose to make the bottle negative, and some may choose to make it positive. This is fine at this point as long as the bottle in their models has a charge, while the hand remains neutral.

- The first model showing interactions between and uncharged hand and an uncharged bottle should show no interaction between the objects.
- The second model with a charged bottle and uncharged hand should show an attraction between the two objects.

Student responses (explanations): Students should have a method for showing how the pieces of tape interacted or moved. For example, students may have used arrows to show which direction the pieces of tape moved.

- I used arrows to show when the pieces of tape were moving together, or moving apart.

18. How do your models explain your observations of the interactions between two charged objects, or a charged object and uncharged object?

Student responses: Students should connect their model with the observations.

- The simulation showed that objects with similar charges repelled, so the pieces of tape that repelled each other must have similar charges.
- The charged water bottle and the paper were attracted to each other even though the paper had a neutral charge.

19. What patterns can you find in the relationship between the charge of two objects and how they interact with each other?

Student responses:
- If two objects have the same charge (both positive or both negative), they will push away from each other.
- If two objects have different charges, they will be attracted to each other.
- If one object is charged, and the other object is neutral, they will attract each other.

Look at your classmates' models and compare how they are similar to and/or different from your model.

Discussion of Models
Display students' models and discuss them. It is important to make sure students understand that there are no "right" models and that the discussion should just focus on how different models may highlight different relationships, causes, or observations.

You may want to first spend time discussing the tape models, then move to discussion the water bottle and the hand before talking about similarities and differences between the models.

Possible questions:
- *Do you notice any similarities and differences in the models we drew?*
- *Which models are most useful for explaining how the different types of tape interacted?*
- *Which models are the most useful for explaining how the water bottle interacted with your hand?*
- *What are some different ways students explained their observations?*
- *What additional questions could we ask or what additional evidence do we need to revise our models?*

Note: At this point, students do not have evidence to determine which object is negatively charged and which object is positively charged. This is a good thing to point out in the discussion.

Build a consensus model as a class.
- Ask students about the connection between the model and the phenomenon.
- Ask students about patterns that they observed in the tape activity and

Homework:
Reading 2 for Activity 1.3: Electric Interactions in Daily Life

Activity 1.4 How do I know if something is positively or negatively charged?

SUMMARY

Students will apply the patterns of attraction and repulsion they developed in the previous activities to deduce the charge of an object, using an object of known charge as a reference. In particular, they will design a procedure to determine the type of charge on two strips of tape. In addition, students will learn to support a claim with evidence as a first step toward using the claim-evidence-reasoning framework. (See Appendix for more information about the claim-evidence-reasoning framework.) Identifying whether objects are neutral or charged, and whether the charge on an object is positive or negative can provide important information that students may need to make predictions about the interactions between various objects.

LEARNING GOALS

- Students will design and carry out an investigation to determine the charge of an object using an object of known charge as reference and their model of electrostatic interactions.

Disciplinary core idea	Crosscutting concept	Science and engineering practice
PS2.B Types of Interactions: Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects (NGSS Lead States, p. 95).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82)	*Planning and carrying out investigations:* Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. (NGSS Appendix F p. 53).

- Students will collect and interpret data to determine the type of charge an object has.
    - At this point, the student model of electrostatic interactions contains rules for interactions of charged objects (the same charges repel; opposite charges attract; charged and uncharged attract) that can be used to explain and make predictions about electrostatic phenomena.

Disciplinary core idea	Crosscutting concept	Science and engineering practice

Activity 1.4 - Teacher Preparation

PS2.B Types of Interactions: Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects (NGSS Lead States, p. 95).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82)	*Analyzing and interpreting data:* Use tools, technologies and/or models to generate and analyze data in order to make valid and reliable scientific claims (NGSS Appendix F p. 54).

POINTS FOR CONSIDERATION

- Learning how to effectively back up a claim using proper evidence can be difficult for students. It will be necessary to consistently push students to support their claims with evidence, both during class discussions and in their written responses.
- Having students design and carry out their own investigation can take additional class time as students work through their observations, evidence, and ideas. Taking time to think, reflect, and make connections is an important aspect of science learning and so additional time has been built into this lesson.

PREPARATION

Class Time: 90 min.

Materials (for each group)

- Scotch tape
- balloon
- piece of thread (about 1 meter long)
- several rods to charge (may include Teflon, glass, wood, acrylic, or hard rubber)
- fur
- silk
- isopropanol wipes

HOMEWORK

Reading for Activity 1.4: How Do Materials Become Electrically Charged?

Activity 1.4 - Teacher Preparation

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Introduction
    a. Discussion-Introducing the lesson

2. Setting up the experiment
    a. Material management and experimental set-up

    b. Discussion after set-up is complete

3. Using a balloon to determine charge
    a. Students investigate with rod and balloon

    b. Collecting data

    c. Discussion of results

4. Design and carry out your own investigation
    a. Discussion-experimental plans/procedure

5. Making claims based on data
    a. Students answer questions

    b. Wrap-up discussion

Activity 1.4 (Student materials) *How do I know if something is positively or negatively charged?*

Discussion:

Review the reading about Electric Interactions in Daily Life.

Possible questions:

- *What was your favorite example from the reading? Can you describe it to me?*
- *What are some additional examples of electrical interactions that you have experienced at home? (Sparks when folding blankets when the air is dry).*
- *If you were an insect trying to sneak past a spider web, would you want to have be a charged insect or a neutral insect? Why?*

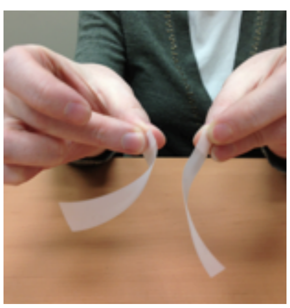
Page title:

Introduction

Introducing the Lesson

- Discuss with students the importance of using evidence to support their ideas. It would be good to include some examples related to everyday life, using the claim-evidence-reasoning framework provided in the Appendix. (Students will incorporate the reasoning aspect of the framework later in the unit.)
- Refer to the driving question board and introduce the new activity-level driving question: *How do I know if something is positively or negatively charged?*
    - Make connections to the prior tape and water bottle activities, and the fact that students cannot know from their observations the specific charge [(+) or (-)] on anobject.
    - Ask students to try to think of a way to tell what the charge on objects is. Students will likely suggest something about using an object of known charge to determine the charge of the tape. This will lead right into the hands-on part of the activity.
    - Remind students that they will be making a claim about the charge of objects, and that they will need to gather evidence to support their claim.

You have seen that two objects with opposite charges attract each other, and two objects with the same charge repel. For example, in a previous activity, you observed how charged strips of tape attracted or repelled each other. How could you have determined which of the pieces of tape were positively or negatively charged?



These pieces of tape have the same charge, but are they both positively charged or both negatively charged?

In this activity, you will create a set of charged objects that can be used to determine the charge of other objects.

Page title:

Setting up the experiment

Materials

- Scotch tape
- balloon
- piece of thread (about 1 meter long)
- bag of different rods
- fur
- silk
- isopropanol wipes

		 Negatively charged balloon
1. Hang a balloon so that it hangs freely and is not too close to anything else.	2. Hold the balloon by the knot and rub the entire surface of the balloon with the piece of fur or wool to charge the balloon.	3. Let the balloon go, trying not to allow its surface to touch anything. The balloon is now negatively charged.

Tip: Make sure the balloons are hanging far enough away from other things so that the balloons will not be attracted to them. Attraction between neutral objects and charged objects is covered in later activities. At this time, it is best to keep students focused on interactions between charged objects.

Naming the Charges The two types of charges—positive and negative—were named by Benjamin Franklin. Rubbing glass with silk caused both objects to become charged. He called the charge on the glass “negative” and the charge on the silk “positive.”	 *Credit: An engraving of Benjamin Franklin's kite experiment, from page 159 (Fig. 82) of "Natural Philosophy for Common and High Schools" (1881) by Le Roy C. Cooley.* *License: Public domain* *Image source: http://commons.wikimedia.org/wiki/File:Franklin_lightning_engraving.jpg*

Discussion

After the setup is complete, discuss the procedure with students.

- *Why is it important to know what the charge of the balloon is?*
- *How does this setup relate to the question we are trying to answer?*

Page title:

Using a balloon to determine charge

Investigate

- Choose one rod and rub it with fur.
- Bring the rod close to the negatively charged balloon and observe what happens. *Try not to touch the balloon with the rod.*
- Record your observations in the table.
- Repeat with each rod.
- Remove the charge from the rods by using the isopropanol wipes and letting the rods dry.
- Then repeat the above procedure using silk as a rubbing material for the rods.

Type of Rod	Rubbing Material	Observation: Does it attract or repel?	Interpretation: Charge of rod

1. **[drawing prompt} Take a snapshot of your table when you complete your observations.**

Discussion

When students have finished the rod-charging activity, have them share their results. It is important that everyone has the same set of rods with known charge. If there is some variation between groups as to the charge obtained with certain rod/rubbing material combinations, those rods will add extra experimental error in the next part. This is a good opportunity to discuss experimental variation

Possible questions:

- *Why do you think there are variations in what we observed?*
- *How can we minimize the variation?*
- *Which rods would be best to use as objects of known charge?*

If there is significant variation for certain rods, it may be prudent to not use those rods to determine the charge on the tapes.

Page title:

Design and carry out your own investigation

2. Using your results from the table, develop a procedure to collect the evidence you need to determine the charge of the T and B tape strips. Describe your procedure below.

Supplemental content: Observing the interactions between an object with a known charge (negative balloon) and an object with unknown charge such as the rods yields the unknown objects charge.

- *Clarification: it does not matter which type of rod (pos or neg) the student selects as long as they can explain their procedure and how it will work.*

Student Responses:

- Rods that attracted to the balloon must have had a positive charge, so using those to test the tape strips can tell us which tape is positive and which tape is negative. The negative tape will attract to the positive rod, and the positive tape will repel from it.

Discussion

Students will be asked to make scientific claims and support them with evidence. Be sure to introduce this practice and discuss its importance.

Scientists try to answer questions about how the world works. They rely on evidence to form and support their answers. In science, whenever you make a claim (a possible answer to a question), you need to support that claim with evidence.

Possible questions:

- *What are some sources of evidence that we have encountered so far?*
- *How can you make sure your scientific claims are convincing?*

Have students share their procedures and discuss the pros and cons of various plans.

- Discuss if/why some procedures might be more useful than others for providing evidence to support claims (e.g., reproducing results, testing with multiple objects).
- Encourage students to modify their plans after they hear ideas from other groups.

3. Carry out your experiment and record what you observed, <u>not your conclusions</u>. Your observations should just be a description of what you saw. You will use these observations as evidence to support your claims.

Student responses: Students should record interactions between the charged objects. They might also include conclusions (or may only include conclusions). Try to help them focus on only recording data, which will be used as evidence in the next set of questions.

Page title:

Making claims based on data

4. Based on your observations, make a claim about the charge of the T strip of tape.

A. The T tape is positively charged.
B. The T tape is negatively charged.
C. The T tape is not charged.

Note: The T (top) tape typically becomes negatively charged, and the B (bottom) tape typically becomes positively charged. This is because the sticky side of the T tape obtains electrons from the non-sticky side of the B tape.

**However, this depends on the type and brand of tape that was used.

5. What evidence do you have to support your claim? (Just record observations here.)

Student responses: Students should describe at least one, or ideally more than one, interaction with oppositely charged rods.

- The negatively charged rod repelled the T tape and attracted the B tape.

6. Explain how your evidence supports your claim.

Student responses: Students should use the opposites attract principle combined with specific observations to indicate whether the tape is positive or negative.

- Opposites attract and likes repel. The T tape must be negative since it was repelled by the negative rod (likes repel).

7. Based on your observations, make a claim about the charge of the B strip of tape.

A. The B tape is positively charged.
B. The B tape is negatively charged.
C. The B tape has no charge.

8. What evidence do you have to support your claim?

Sample answers: Students should give evidence similar to the previous question. Some may also cite the interactions with the T tape, the charge of which has been established in the answers to the previous questions.

- A: Opposites attract and likes repel. The B tape must be positive because it was attracted to the negative rod (opposites attract).
- A: The B tape must be positive because the T tape was negative. In our other activity the two tapes attracted each other and opposites attract.
- B The B tape is negatively charged: The B tape pointed toward the negatively charged rod, so it must be negative.
  - *Ask students what the relationships were between charges on tape (opposites attract and likes repel). Then ask them to re-examine the interaction they saw.*
- C Not Sure: All we know is that opposites attract and likes repel, I am not sure how we can tell which is which.
  - *Ask students what the relationships were between charges on tape (opposites attract and likes repel). Then ask them to re-examine the interaction they saw.*

9. Explain how your evidence supports your claim.

Student responses: Students should use the opposites attract principle combined with specific observations to indicate whether the tape is positive or negative.
Opposites attract and likes repel. The B tape must be positive since it was attracted by the negative rod (opposites attract).

Discussion

- Have students share their conclusions.
- Create a class data table to tabulate the results of each group. If there are groups that disagree, have them discuss their evidence.

This is an opportunity to discuss how to evaluate evidence.

Possible questions:

- *If you were going to design this experiment again, would you change anything to be more sure your claim is correct?*
- *How much evidence would convince you that your claims or ideas are correct?*
- *Does combining the data from the whole class increase or decrease how sure you are about your claim? Why?*

Note: Do not tell students how the pieces of tape obtain their type of charge. Students will come back to this in a future investigation, in which they will determine how the tape strips are charged.

HOMEWORK

Reading for Activity 1.4: How Do Materials Become Electrically Charged?

Activity 1.5 How does an object's charge affect its interactions with neutral objects?

SUMMARY

The previous activities exposed students to interactions between charged and neutral objects. In Activity 1.5, students will collect evidence to support the idea that neutral objects are attracted to both positively and negatively charged objects. This activity provides more evidence for the unit-level driving question: *Why do some clothes stick together and other things don't?* This activity may prompt the following questions: *Why are neutral objects attracted to both positively and negatively charged objects?* and *How can materials contain both positive and negative charges?* Students conclude this investigation by playing a game that requires them to apply what they have learned about electrostatic interactions between charged and uncharged objects. In addition, they revisit their models of the aluminum pie pan demonstration and revise them based on evidence collected during this unit.

LEARNING GOAL

Students will further develop a conceptual model of electrostatic interactions by generalizing the patterns of interactions between charged and neutral objects.

- Clarification: At this point, the student model should include the following:
    - Objects with opposite charges attract each other; objects with the same charge repel.
    - Neutral objects and charged objects are attracted to each other.

Disciplinary core idea	Crosscutting concept	Science and engineering practice
PS2.B Types of Interactions: Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects (NGSS Lead States, p. 95).	*Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena (NGSS Appendix G p. 82)	*Developing and using models:* Develop, revise and use models to predict and support explanations of relationships between systems or between components of a system (NGSS Appendix F p. 52).

Activity 1.5 - Teacher Preparation

PREPARATION

Class Time: 60 min.

Materials (for each group)

- Scotch tape
- thread
- Teflon rod
- glass rod
- fur
- silk
- 3 neutral objects (potential objects: plastic straws, toothpicks, paper clips, small pieces of wax paper, small pieces of aluminum foil, feathers, various kinds of fabric, ribbon)
- at least 1 neutral object of students' choice (not from the above list)

Activity Setup

- Construct a materials kit for each group.

HOMEWORK

Reading for Activity 1.5 Why Do We Revise Our Models?

Activity 1.5 - Teacher Preparation

BASIC OUTLINE OF ACTIVITY

Use this space to make notes to prepare for your lesson

1. Introduction
    a. Discussion

2. Investigate
    a. Collecting data

3. Analysis
    a. Discussion

    b. Balloon demonstration

4. Applying your knowledge to win a game
    a. Discussion-playing the game

    b. Revising pie pan models

    c. wrap-up

Activity 1.5 (Student materials) *How does an object's charge affect its interactions with other objects?*

Discussion:

Review the reading How do Materials Become Electrically Charged?.

Possible questions:

- *What are some different ways that objects become charged?*
- *If you are outside during bad weather and your hair starts to stick out, what should you do? Why? How does that happen?*
- *Why is it that sometimes we shock ourselves when we touch something metal? Have you ever shocked someone else? How do you think you built up a charge?*

Page Title:

Introduction

1. The plastic bottle used in a previous activity became negatively charged when rubbed with fur. What do you think will happen if a positively charged object is brought near a neutral object?

A. They will attract each other.
B. They will repel each other.
C. Nothing. They will not interact.

Student Responses: Students are not expected to answer this question correctly. It is just meant to engage them and provide something to refer back to at the end of the lesson.

- A. They will attract because the neutral paper was attracted to charged objects.
- B. Well if the neutral object was attracted to the negatively charged object, it must repel from the positively charged object.
    - *Encourage students to explain why they selected this answer. Ask student what it means for an object to be neutral.*
- C. Neutral objects do not interact because they don't have a charge.
    - *Ask students if the charged object will have an effect, why or why not.*

Discussion

To guide the discussion, choose responses that represent the range of students' ideas about the driving question for this activity *How does an object's charge affect its interactions with neutral objects?* Ask students to provide support for their predictions.

To set up today's activity, brainstorm as a class how to investigate whether the charge of an object affects its interactions with a neutral one.

- Students will need objects of known charge to investigate this. Brainstorm ways of getting such objects.

Page Title:

Investigate

Materials

- Thread
- Teflon rod
- glass rod
- fur
- silk
- Thread (about 10 inches long)
- Thin piece of paper (about 2x5 inches)
- 3 neutral objects

In Activity 1.4, you created both positively charged and negatively charged rods. As you have seen, **rubbing a Teflon rod with fur will cause the rod to become negatively charged, and rubbing a glass rod with silk will cause the rod to become positively charged**. Use this information to create a positively or negatively charged rod as needed below.

Investigate
Suspend a piece of paper from the thread, making sure it is not touching anything else.

Charge one of the rods. Bring the rod close to the suspended piece of paper and record your observations in the table.

Repeat the process with an oppositely charged rod.

In the table, record what happens when each charged rod is brought close to each of the neutral objects.

Charge on Rod	Neutral Object	Observation

2. Take a snapshot of your table when it is complete.

Page Title:

Analysis

3. Based on your observations, what patterns do you see in the way neutral objects behave when charged objects are brought near them? Be sure to support your answer with evidence.

Student responses:

- All objects tested were attracted to the negatively charged rod, and all objects tested were attracted to the positively charged rod. So it seems that neutral objects are attracted to both positively and negatively charged objects.
    - *If students do not have or remember the necessary evidence, prompt them to retest the objects and use that evidence.*

Discussion

Tabulate the data for the entire class to show that a broad range of neutral objects all yield the same results.

Possible questions:

- *What patterns do you see in the data?*
- *How do they compare with your group's results?*
- *What can we conclude about the interactions between neutral objects and charged objects?*
- *Revisit students' original ideas about whether the type of charge matters, and see if they still agree with them. Make sure students provide evidence as to why or why not.*

Work to reach a consensus that neutral objects and charged objects attract regardless of the type of charge.

Note: If students choose a heavy neutral object, it may not move. If this happens, ask questions like:

- *Are the neutral and charged objects still attracted to each other if you can't see them move toward each other?*

There is not enough force from the rod to make the heavy object move. (An analogy one person can't move a full file cabinet no matter how hard he pulls or pushes on it, but he still exerting a force on it)

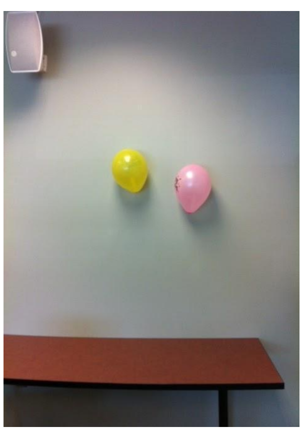
- *Would positive and negative objects always move toward each other? Will there be an interaction between them?*

An optional extension could include designing a detector for movement that may not be easily observable. For example, students could attach a piece of foil to an object and reflect a keychain laser pointer off of it and see very small amounts of movement in the reflection.

4. What does the data from your entire class indicate about what happens when neutral objects interact with charged objects?

Student responses:
- Lightweight neutral objects seem to be attracted to charged objects, no matter what the charge is.

After it is rubbed with fur, a balloon will stick to the wall.



5. What characteristics could the wall have that would cause the negatively charged balloon to stick to it? Include reasons for your answer.

Student responses: Although the lesson has been focused on interactions between charged and neutral objects, one possible answer is that the wall is positively charged.

- The wall could be positively charged, causing the negatively charged balloon to stick to it.
    - *Challenge students: Ask students to explain how the wall might get and maintain a positive charge. Ask them how they might test this.*
- The wall could be neutral.

Demonstrate how a balloon sticks to a wall. Have the class brainstorm what characteristics a neutral object (e.g., the wall) might have so that it is attracted to both a positively and negatively charged object.

Note: Ask students to support their explanations, but do not evaluate their responses. Students may think that a neutral object has no charge, can easily change charge, or is both positively and negatively charged. Students may also have other ideas. The goal here is for students to start thinking about what might be happening. Students will answer this question later and do not need to agree on an explanation at this point.

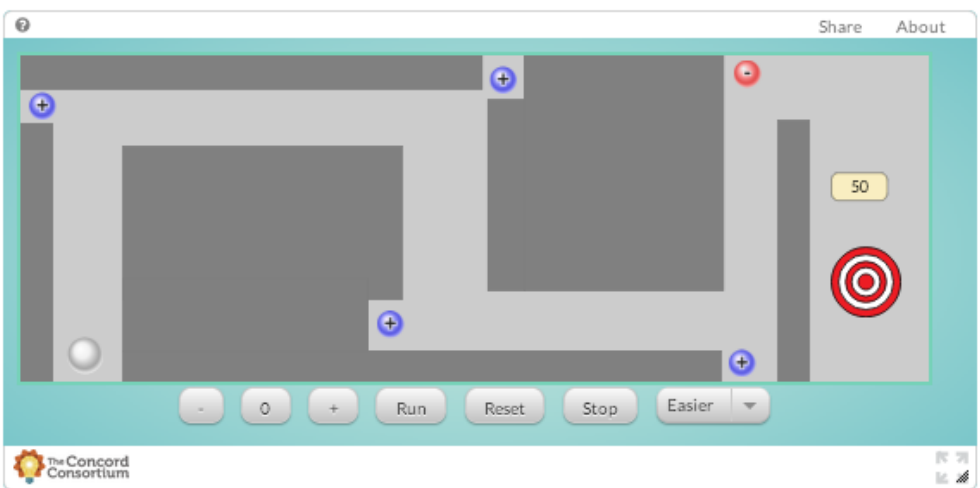
Page title:

Applying your knowledge to win a game

Discussion
Explain that scientists use models to help explain phenomena they observe. They study and test the phenomena, and then revise the models so that they provide a better explanation of the phenomena. Students will now do the same thing. In the past few activities, students have been developing their own models of interactions between charged objects to explain why some objects stick together and others don't. In this activity, they will return to the models they created to explain the pie pan demonstration and modify them to include new ideas they have learned.

Over this investigation, you've developed a model that can be used to explain and predict how charged objects interact with each other. Now, apply what you have learned and test your knowledge about interactions involving charged and neutral objects by playing the Maze Game.

1. Your goal is to move the white ball to the target area before time runs out.
2. Click **Run**. Then click (**–**) to put a negative charge on the white ball, (+) to put a positive charge on the ball, or (**0**) to make it neutral.
3. When you are finished, take a snapshot as proof you won the game.



Simulation link: http://lab.concord.org/interactives.html#interactives/interactions/mazeGame.json

6. Place a snapshot of your winning game here.

Page title:

Improving models of the pie pan demo

Discussion

Students may ask why they need to come back to this phenomenon, since they already made a model of it. This would be a good time to discuss the homework reading about revising models (Reading for Activity 1.3).

- Remind students that they now have much more knowledge that they can apply in order to revise and update their original models.
- Help students understand the process of scientific inquiry. Discuss the role of revisiting and revising models in the development of better understandings of phenomena.

Think back to the Van de Graaff aluminum pie pan demonstration you saw at the beginning of this investigation. Click on the link below if you want to see it again.

Van de Graaff and pie pans

Think about what you've learned since you first saw this demonstration and how you can use that knowledge to explain what caused the pans to behave the way they did.

7. [drawing prompt] Create a series of drawings that show why the pie pans behaved the way they did. Make sure to label your drawings.

[text prompt] Explain what is happening in each step of your drawing.

Student responses: Students' drawings should be more detailed than the models they drew in Activity 1.1.

- The drawings should now include charges and possibly forces, whereas the original drawings may not have included these components.
  - *Students are not expected to include ideas such as charge transfer.*

Concluding the Lesson

Revisit the unit-level driving question: *Why do some things stick together and other things don't?*

Possible questions:

- *What have we learned to help answer the question,* Why do some things stick together and other things don't? *(Add ideas to the DQ board that help answer the question. Modify models on the board to better answer the question.)*
- *How does this help explain why some clothes stick together when they come out of the dryer?*
- *What questions do we still have about what makes some clothes stick together in the dryer?*
- *What do we need to figure out to develop an even better answer?*

HOMEWORK

Reading for Activity 1.5 Why Do We Revise Our Models?