Companion Lesson

Investigating Non-Touching Forces

Overview

This hands-on activity builds on and reinforces students' understanding of motion and kinetic energy, as well as concepts involving forces, including non-touching forces, from earlier grades. Students explore magnetic and electrostatic forces, then discuss the variables that might affect the strength of those forces. The teacher models how to plan an investigation that explores the effect of distance between objects and magnetic force strength. Next, students design their own investigations that are intended to gather evidence about other factors that could affect the strength of magnetic or electrostatic forces. The purpose of this lesson is for students to engage in planning and conducting investigations that will help them discover patterns in what affects the strength of magnetic and electrostatic forces, including distance between the objects involved, magnet strength, and amount of electric charge. This lesson prepares students to learn about magnetic, gravitational, and electrostatic fields in the next New York City Companion Lesson: Reading About Non-Touching Forces.

Recommended Placement: *Harnessing Human Energy*, after Lesson 3.3
Suggested Time Frame: two 45-minute class periods

Vocabulary

- electrostatic force
- force
- kinetic energy
- magnetic force

Materials & Preparation

Materials

For the Class

- Investigating Non-Touching Forces copymaster
- 1 balloon pump
- water*
- 3 large index cards*
- marker*

For Each Group of Four Students

- 1 tray*
- 1 ruler
- 2 strong magnets
- 2 weak magnets
- 10 paper clips*
- 2 balloons
- 1 piece of faux fur fabric
- 1 piece of cotton flannel
- 1 moist paper towel or dishcloth*
- 10 foam packing peanuts

For Each Student

- Investigating Non-Touching Forces student sheets*

*teacher provided

Preparation

1. **Print Investigating Non-Touching Forces copymaster.** Locate the Investigating Non-Touching Forces

Materials (continued)

copymaster on the Richmond webpage: www.amplify. com/ richmondscience. Make one copy of all pages for each student.

2. **Create and post vocabulary cards on the classroom wall.** With a marker, write “force,” “magnetic force,” and “electrostatic force” in large print on separate index cards. Post these cards on the classroom wall.
3. **Inflate balloons.** Inflate two balloons for each group of four students. Use your mouth or the balloon pump. Alternatively, you could have students inflate the balloons while you are distributing materials.
4. **Moisten paper towels.** For each group, moisten a paper towel or a dish cloth with water.
5. **Prepare trays of materials.** For each group of four students, place the following materials on a tray:
    - 1 ruler
    - 2 strong magnets
    - 2 weak magnets
    - 10 paper clips
    - 2 balloons
    - 1 piece of faux fur fabric
    - 10 foam packing peanuts
    - 1 moist paper towel
6. **Prepare to model how to plan an investigation.** As a class demonstration, you will model completing Part 2: Investigating Strength of Forces from the Investigating Non-Touching Forces student sheets (checking the option for magnetic force). You could either use a document camera or recreate the questions on a large sheet of chart paper. Student pairs will later use these pages to plan their own investigations.
7. **Locate and review rubrics.** Review the Rubrics for Assessing Students’ Investigations of Non-Touching Forces in the Assessment section of this lesson. These rubrics can help you plan ways to support students as they complete their investigations and draw conclusions during the lesson. After the lesson, use the rubrics to formatively assess students’ developing facility with science and engineering practices and their understanding of disciplinary core ideas.
8. **Immediately before the lesson, have on hand the following materials:**
    - student sheets
    - trays of materials

Notes

Additional Materials

Providing additional materials—rods and/or additional types of cloth—will enrich student explorations of electrostatic force, and may result in students producing stronger or more reliable forces, depending on the conditions in the classroom (especially humidity). On the other hand, students should be be able to observe clear evidence of electrostatic force using just a balloon, foam peanuts, and faux fur. Many science supply companies sell sets of rods of various materials for use in exploring electrostatic force. If you only have a few of these sets, you could have pairs pass them around during testing. Small pieces of cloth can be purchased at fabric stores or you can purchase inexpensive used clothing and cut it apart.

Science Background

A force is a push or a pull that can change the motion of an object. A force can cause an object to change its motion—e.g., start moving, stop moving, or change direction and/or speed. Since forces can affect movement, they can also affect the kinetic energy of objects. Forces can be contact forces (e.g., your foot kicking a ball) or non-touching forces. Non-touching forces include magnetic force, electrostatic force, and gravity. A magnet is an object that can exert a magnetic force on other magnets and on objects made of certain metals. The magnetic force is the push or pull between two magnets or the pull of a magnet on some kinds of metal. Magnets always have two poles—a north pole and a south pole. Magnets exert force at a distance; the magnetic force between like poles is repelling, while the magnetic force between opposite poles is attracting. A magnet can temporarily create magnetic poles in objects made of certain types of metal (e.g., iron), so the magnetic force is attractive between a magnet and the metal object. The strength of the magnetic force diminishes with distance. Some magnets are stronger than others, and therefore produce stronger magnetic forces. Electrostatic force (also called Coulomb's force) is the push or pull between two objects due to their electric charge. If the charges of the objects are the same (both positive or both negative), the force is repelling; if the charges are opposite, the force is attracting. Like magnetic force, electrostatic force diminishes with distance. The larger the magnitude of the charges on the objects, the greater the electrostatic force.

Instructional Guide

Explore and Activate Prior Knowledge

1. **Review kinetic energy.** Ask students to summarize what they have learned so far about kinetic energy. [When something is moving, it has kinetic energy.]
2. **Discuss what can make an object start moving.** Ask students what it takes to make an object start moving. For example, if a ball is resting on the ground, what can make it start moving? [Kicking the ball. Something hitting the ball. A force acting on the ball. Energy being transferred to the ball.]
3. **Introduce the word *force*.**

   A force is a push or a pull that can change the motion of an object.

   Encourage students to ask questions or share what they have learned about forces.

   Point out that the vocabulary word is posted on the classroom wall. Let students know that they can also find the definition in the glossary at the back of their Student Editions.
4. **Discuss non-touching forces.** Ask students if they think a force could make an object start moving if nothing ever touched the object. Accept all ideas. Hold up a tray of materials and explain that students will see if they can make an object start moving without anything touching it. If they succeed in finding one way to do this, they should try to find other ways as well. Explain that objects should stay on the table, but touching the table is not going to count as something touching the object, since the table will not make an object start moving.
5. **Groups explore materials.** Pass each group a tray with materials. Remind them to share materials, making sure all group members get to try the various objects.
6. **Demonstrate charging the balloon with faux fur fabric.** After a few minutes, demonstrate rubbing a balloon with a piece of the faux fur fabric and encourage students to try this if they haven't already. About ten strokes, all in the same direction, should produce good results.
7. **Groups continue exploring.** Give students a few more minutes to explore.

Build Foundational Knowledge

8. **Share observations.** Call on volunteers to demonstrate some ways they found to make an object move without anything touching it. [A magnet attracting a paper clip. A magnet attracting or repelling another magnet. A balloon rubbed with fabric attracts or repels a foam peanut.] Have groups return all materials to the trays and set them aside.
9. **Introduce the terms *magnetic force* and *electrostatic force*.** Explain that these are two examples of forces that can act at a distance—they are both non-touching forces.

   Magnetic force is the push or pull between two magnets or the pull of a magnet on some kinds of metal.

Electrostatic force is the push or pull between two objects due to their electric charge. Rubbing a balloon with fabric makes the balloon electrically charged.

Point out that these vocabulary words are also posted on the classroom wall and the definitions can be found at the back of their Student Editions.

Construct New Ideas

10. **Discuss what might affect the strength of these forces.**

    With touching forces, we know that you can have a stronger force or a weaker force. You can kick a ball hard, or you can kick it gently. Is the same true for non-touching forces? What might affect the strength of a magnetic force or an electrostatic force?

    Invite volunteers to share ideas about what variables might affect the strength of magnetic force, and list all ideas on the board. [Size of magnet. Strength of magnet. How close the magnet is to the object. Whether there is anything between the magnet and the other object.]

    Do the same for ideas about electrostatic forces. [How much you rub the balloon. The material you use to rub the balloon. How close the balloon is to the foam peanut. Whether there is anything between the balloon and the packing peanut. How long you wait after rubbing the balloon.]

    Keep these lists of variables on the board for the rest of the lesson. If you will be teaching part of this lesson on a different day, you may need to transfer the lists to chart paper or some other way of safekeeping the information.

11. **Introduce both investigations.** Explain that the class will first work together to plan an investigation about one variable that might affect the magnetic force strength. Once the planning is complete, students will work in pairs to conduct the investigation and record the data. Then, each pair will plan and conduct their own investigation of another variable that might affect the strength of a non-touching force—either magnetic or electrostatic.

12. **Model planning the first investigation.** Use a document camera to project Part 2: Investigating Strength of Forces, from the Investigating Non-Touching Forces student sheets, or use the large chart paper version you prepared.

    - **Step 1.** Check "magnetic force" and explain that the first investigation will focus on magnetic force.
    - **Step 2.** Write "distance between magnets" and explain that the investigation will gather evidence about whether the distance between magnets affects the strength of the magnetic force.
    - **Step 3.** Explain that it will be easiest to test the strength of force if you use repelling magnets. That way you can measure how far one magnet is pushed away by the

other. You can hold both magnets still, then release one so it is pushed across the tabletop. Write "repelling magnets, side-by-side, release one so it is pushed away"

- **Step 4.** Point out that you should decide ahead of time on the exact starting distances to test. Write "0 cm apart, 1 cm apart, 2 cm apart, 3 cm apart."
- **Step 5.** Invite students to share ideas for measuring. Agree on using a ruler and a standard way of measuring distance travelled (e.g., to the part of the magnet that travelled the farthest or the part of the magnet that is closest). Record the method that the class agrees upon.
- **Step 6.** Review the importance of controlling other variables. Invite students to offer suggestions for variables that need to be controlled. [Strength of magnets. Surface magnets will slide over. Arrangement of magnets.]
- **Step 7.** Ask students why it might be important to do more than one test at each distance. [In case something goes wrong on one test.] Write "Three times at each distance."

13. **Distribute the Investigating Non-Touching Forces student sheets and introduce the data table.** Direct students to Part 1: Distance and Strength of Magnetic Force. Review how to record results in the data table.
14. **Conduct one test as a demonstration.** Demonstrate by holding the magnets 0 mm apart (touching each other). Hold the magnets together, side-by-side with like poles touching. Release one magnet while holding the other still. Measure the distance the magnet travelled using the method that the class agreed upon.
15. **Pairs continue to conduct the investigation.** Have pairs conduct the investigation, but ask all students to record the results on their student sheets. Remind students to take turns handling the magnets and doing the measuring.
16. **Share conclusions.** As pairs finish, have them discuss with another pair and write about whatever pattern they think the evidence shows about distance between magnets and strength of magnetic force. [Force decreases as distance increases.] When all groups have finished, discuss as a class.
17. **Introduce independent investigations.** Refer back to the lists of variables that the class made earlier in the lesson. Explain that each pair will choose one of the variables that could affect the strength of magnetic or electrostatic forces. Each pair will plan and conduct their own investigation, using the Part 2: Investigating Strength of Forces and Part 3: Investigation Results student sheets.
18. **Describe using a moist paper towel to make the balloon lose its charge.** Tell students that rubbing the balloon a couple of times with the moist paper towel, then letting the balloon dry, will usually work to make the balloon lose its charge. Students may want to do this between each test before charging their balloon again.

19. **Each pair chooses another possible variable to investigate.** Have each pair discuss and choose one of the possible variables listed on the board, for either magnetic force or electrostatic force. Then, direct students to Part 2 and have them complete steps 1 and 2 (the force and the variable).
20. **Discuss ideas for observing or measuring strength of force.** Ask for ideas on how students will gather evidence about the strength of forces. Encourage students to share ideas, ask each other questions, and respond to each other's ideas. Ideas that students suggest might include measuring how far an object moves; holding a paper clip, peanut, or magnet so it can't move and feeling the strength of the force on it; testing how much weight can be moved by a force, perhaps by adding weight to a paperclip or peanut; and testing how far apart objects can be and still have the paper clip or foam peanut start moving.
21. **Pairs plan investigations.** Have each pair discuss their plan for the investigation and record it in Part 2. As needed, remind students to conduct multiple tests, and change only one variable between each test. You may want to allow students to use materials other than those on their trays, as long as the materials are available in the classroom.
22. **Pairs discuss and share plans within their groups.** Have pairs share their plans with the other pair in the group. Encourage pairs to ask clarifying questions about their plans and to offer suggestions to the other pair. Encourage students to revise their plans as needed.
23. **Pairs conduct investigations.** Have pairs begin conducting their investigations and record the results in Part 3. Help students share materials, and if necessary, trade materials from one group to another.
24. **Share results and conclusions.** Call on students to share the results of their investigations. As it can be challenging to measure the strength of forces, don't be surprised if some pairs have inconclusive results.
25. **Emphasize similarities between magnetic force and electrostatic force.** Explain that both forces can act at a distance, and the strength of each force is affected by the distance between the objects involved. The strength of a magnetic force is affected by the strength of the magnet, and similarly, the strength of an electrostatic force is affected by the strength of the charge on an object. For example, the more a balloon is rubbed by a piece of felt, the more charged the balloon becomes and the stronger a force it is able to exert.

Apply New Ideas

26. **Introduce the scenario.** Direct students to Part 4: Magnetic Device Problem. Review the scenario and help students understand it. Give students a few minutes to write their responses.
27. **Discuss students' responses as needed.**

Rubrics for Assessing Students' Investigations of Non-Touching Forces

The rubrics below may be used to review students' investigation plans and conclusions to formatively assess students' developing facility with science and engineering practices and understanding of disciplinary core ideas.

Rubric 1: Assessing Students' Performance of the Practice of Planning and Conducting Investigations

Note that this rubric applies to students' investigation plans and results in Part 2: Investigating Strength of Forces and Part 3: Investigation Results of the Investigating Non-Touching Forces student sheets. Rubric 1 is designed to monitor and support students as they develop dexterity with the practice of Planning and Conducting Investigations. For each criterion, levels are described to monitor students' progress by indicating the degree to which students can independently demonstrate fluency with the science practice. This rubric may be used formatively to support students' facility with the practice of Planning and Conducting Investigations. It features targeted questions that a teacher may use to assess students' design plans, and it provides specific feedback for revisions and for future encounters with the practice.

Note: Students may investigate a variable of their choice, and therefore their responses will vary. The examples provided are for an investigation of how the strength of a magnet affects the strength of force.

Rubric 1: Assessing Students' Performance of the Practice of Planning and Conducting Investigations

Criteria	Description and possible feedback	Level
Produces data that can serve as the basis for evidence. Could the data generated by the investigation be used as evidence to support an answer to the question?	Students don't specify the data that will be collected. Possible feedback: *What information will you be able to observe as you conduct your investigation?*	0
	Students specify the data that will be collected, but the data indicated could not serve as evidence to answer the question. Example: We will observe the direction of the second magnet's movement. Possible feedback: *How will your data help you answer your question?*	1
	Students specify the data that will be collected, and the data indicated could serve as evidence to answer the question. Example: We will observe how far the second magnet moves when we release it.	2

(Table continues on the next page.)

Rubric 1: Assessing Students' Performance of the Practice of Planning and Conducting Investigations (continued)		
Criteria	**Description and possible feedback**	**Level**
Plans for fair tests: identifies variables to control. Does the investigation plan identify variables that will be controlled in order to have fair tests?	Students don't specify any variables that will be controlled. Possible feedback: *What else could cause your results to change? How can you make sure that won't affect your investigation?*	0
	Students specify which variables will be controlled but choose variables that are not relevant or miss variables that would impact the investigation. Example: We will have the same person hold the first magnet still during each test. Possible feedback: *How would that affect your investigation? What else could affect your investigation? How can you make sure that won't affect your investigation?*	1
	Students specify which variables will be controlled, and they choose variables that would impact the investigation. Example: We will release the second magnet from the same place, and it will be the same distance from the first magnet in every test. Possible feedback: *Is there anything else that could affect your investigation?*	2

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Note that this rubric applies to students' responses in Part 4: Magnetic Device Problem of the Investigating Non-Touching Forces student sheets. Rubric 2 considers whether students have constructed and applied ideas in a way that is consistent with accepted science ideas. This rubric is designed to be formative, and space is provided to note whether students are demonstrating understanding or if they are struggling with each idea. If students are having difficulty with a particular idea or with multiple ideas, you might consider returning to the data collected during the class investigation of force and distance, or you might point to the data from a student-led investigation of force and magnet strength or magnitude of electric charge. Lead a focused student discussion about how the distance between magnets or the strength of the magnet or magnitude of charge affects the distance that the released object moves and what that means about the strength of the force. Help all students conclude that the strength of a force can depend on the distance between magnets, the strength of a magnet, or the magnitude of charge.

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit		
Criteria	**Description**	**Is there evidence of student understanding?**
Consistent with accepted science ideas. Are students' conclusions consistent with accepted science ideas?	Students demonstrate understanding of the idea that the strength of a magnetic force depends on the strength of the magnet. Example (using weaker magnets): Weaker magnets make weaker forces, so they wouldn't move the cart as fast. A slower cart would have less kinetic energy.	
	Students demonstrate understanding of the idea that the strength of a magnetic force depends on the distance between two magnets. Example (using repelling magnets that started out farther apart): When magnets are farther apart, the magnetic force is weaker. A weaker force wouldn't move the cart as fast. A slower cart would have less kinetic energy.	

Investigating Non-Touching Forces

Part 1: Distance and Strength of Magnetic Force

Refer to the investigation plan that you made as a class. Conduct the tests with your partner and record the results below.

Test #	Starting distance between magnets	Distance one magnet moved
1	0 centimeters (touching)	27 cm
2	0 centimeters (touching)	31 cm
3	0 centimeters (touching)	32 cm
4	1 centimeter	12 cm
5	1 centimeter	16 cm
6	1 centimeter	11 cm
7	2 centimeters	5 cm
8	2 centimeters	5 cm
9	2 centimeters	4 cm
10	3 centimeters	1 cm
11	3 centimeters	1 cm
12	3 centimeters	1 cm

What pattern do you think the evidence shows about distance between magnets and strength of magnetic force?

The evidence shows that as magnets get closer they have a stronger magnetic force.

Possible Student Responses

Investigating Non-Touching Forces (continued)

Answers will vary. Examples below.

Part 2: Investigating Strength of Forces

1. Which force will you investigate? (check one)

- [ ] magnetic force
- [x] electrostatic force

2. What variable will you investigate?

Number of times we rub the balloon with the cloth.

3. How will you conduct your tests?

For each test, we will rub the balloon a certain number of times with the cloth, then slowly move the balloon closer and closer to a foam peanut. As soon as the peanut moves, we will measure the distance between the peanut when it started moving and the balloon.

4. How will you change that variable between each test?

Test with 1 swipe of cloth to rub balloon, test with 5 swipes of cloth to rub balloon, test with 10 swipes of cloth to rub balloon, test with 15 swipes of cloth to rub balloon.

Investigating Non-Touching Forces (continued)

5. What will you measure and/or observe in order to gather evidence about the strength of the force?

How far away the peanut is when it starts moving.

6. What will you keep the same for each test?

How far away the balloon is from the peanut at the start of the test, the surface the peanut is on, and how fast we swipe.

7. How many tests will you do?

3 tests for each number of swipes. 12 total tests.

Investigating Non-Touching Forces (continued)

Part 3: Investigation Results

Record the results of your investigation on this page. Create a data table if it helps to organize your results.

Answers will vary.

Investigating Non-Touching Forces (continued)

Part 4: Magnetic Device Problem

One team of engineers builds a device that uses repelling magnets to make a cart move. The moving cart has kinetic energy. A second team of engineers tries to build a copy of the device, but the cart does not move as fast. It does not have as much kinetic energy. The second team used the same cart as the first team, but they made their own version of the repelling magnets.

What might the second team have done differently? Describe two magnet variables that might have been changed. For each variable, explain why the change would have caused the cart to move more slowly and to have less kinetic energy.

First possibility:

They might have used weaker magnets. Weaker magnets make weaker forces, so they wouldn't move the cart as fast. A slower cart would have less kinetic energy.

Second possibility:

They might have had the repelling magnets start out farther apart. When magnets are farther apart, the magnetic force is weaker. A weaker force wouldn't move the cart as fast. A slower cart would have less kinetic energy.