NanoLeap

Investigating Static Forces in Nature: The Mystery of the Gecko
Lesson 6: How MUCH Force Is Needed to Make an Object Stick?
What Factors Affect the STRENGTH of Force Acting on an Object?
Explore

Student Learning Objectives:

- Explain that a net force of zero or greater is necessary for objects to adhere to a surface (wall or ceiling)
- Identify different variables and the constants that affect adhesive forces
- Explain how the amount of adhesion changes when the conditions of the surfaces change

<u>Note: Some questions in the Student Journal are underlined as formative assessment checkpoints for you to check students' understanding of lesson objectives.</u>

At a Glance for Teachers:

- Review what students know about forces
- Teacher demonstration on balanced forces
- Determine the amount of force needed for objects of varying masses to adhere to a ceiling and maintain a net force of zero
- Activity: Tape Pull—Measure the amount of force required to remove a piece of transparent tape with varying amounts of dirt

Estimated Time: 80 Minutes

Vocabulary: Adhere, Adhesive, Balanced Forces, Dependent Variable, Force, Independent Variable, Mass, Net Force, Newton, Unbalanced Force, Volume
Refer to the end of this Teacher Guide for definitions.

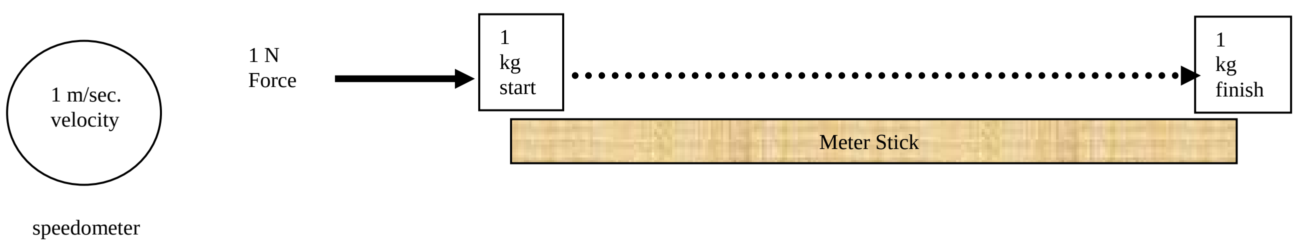
Materials:

- PowerPoint for Lesson 6
- Student Journals for Lesson 6
- Computer with LCD or overhead projector
- Duct tape
- 50 N spring scale
- Transparent tape
- Hole punch
- Ruler, protractor

Safety Note

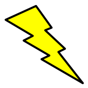
Have students wear safety goggles in accordance with district safety policy.

Slide # **Student Journal Page #**	*Teacher Background Information and Pedagogy* **"Teacher Script"**
Slide 1 Title Student Journal Page: 6–1	1) *Review with students that a* ***force*** *is a push or pull. See definitions in Appendix B.* **"What is the meaning of the word force in science?"** 2) *Demonstrate balanced forces by partially filling a small jar with water. Place an index card underneath the rim of the jar and invert the jar while holding the index card. Next, release your hand from the card while carefully holding the jar. Students should note that the card remains in contact with the rim of the jar. Have students identify the balanced forces at work in this demonstration. Answer: air pressure is the dominate force, it is equal to the weight of the water plus the force of gravity. Other forces that are present but less dominate are gravity and capillary wet adhesion (if the card got wet when it came in contact with the rim of the glass).* **"Is this demonstrating a balanced or unbalanced force? Why?"** **"What would happen if this was an unbalanced force?"** 3) *Have students look around the room and identify pairs of objects that are at rest and represent balanced forces and record these in the box on the left side of the student journal. Students should identify the forces acting on each object and that the net force is zero. Have students draw one of the examples of balanced forces and indicate the amount of each force acting on the object using arrows in Student Journal page 6–1. Have students repeat this exercise for unbalanced forces in the box on the right side of the student journal. Note to teacher: if the object sits on a table, there is the upward normal force of the table on the object. Research has shown that students often don't recognize this as a force, they just indicate the table is in the way.]* 4) *Provide examples of objects in motion such as objects speeding up, slowing down, or at constant speed.* *A field test teacher used a Frayer model for balanced and unbalanced forces for this lesson (refer to Lesson 1 for directions on the use of the Frayer model).*
Slide 2 Student Journal	5) *Display Slide 2* **"In this image, there are two forces at work: one that is holding the shoe onto the ceiling and another that is pulling the shoe towards the floor. In order for the shoe to remain on the ceiling, what must be true about these two forces?"**

Page: 6–1	*Students should state that these represent balanced forces (i.e., the net force is zero), or that the force holding a shoe is greater than the force of gravity. An example of the latter would be if the shoe contained a magnet that was attracted to a steel ceiling. This force could be greater than gravity, and then there would be an additional normal force acting in the direction of gravity to counteract the excess magnetic force.*
Slide 3 Student Journal Page: 6–2 Calculations In Appendix A	**"Imagine an ant, like the one on this slide, walking on the ceiling. Draw a picture representing the forces of the ant on the ceiling in your journal. Determine the force required for each ant foot (divide total force by six)."** *Explain the following assumptions that are important for this problem:* **"We are assuming in this problem that the total force required is equally divided among the six ant feet, and that ONLY the contact between feet and ceiling gives rise to the force."** *The weight of the ant is provided in Newtons (N), a derived unit which is the force needed to increase the speed of (or accelerate) one kilogram of mass one meter per second every second.* *A field test teacher passed around objects (e.g., a one Newton weight, an eight Newton cell phone) for students to be able to relate to this unit of measure.* *For this module, there is no need to calculate force with Newton's Second Law of Motion. However, there may be a need to explain how an object's weight can be expressed in Newtons. Explain that in the metric system forces are measured in units of Newtons (using the symbol "N"). Provide students with the definition found in Appendix B along with the following illustration. Use these along with the direct vocabulary instruction strategy as described in the preface. Weight is action of the force of gravity on an object. A standard kilogram mass would therefore have a weight of 9.8 Newtons on Earth since the acceleration due to gravity is 9.8 m/s/s.* 

	6) *Point out to students that the weight is the minimum amount of force that must be provided by the feet of the ant on the ceiling in order for there to be balanced forces and thus have the ant adhere to the ceiling. See Appendix A for the answers.* ***Note:*** *During the pilot test, students thought this activity was interesting. The calculations took a bit to understand, and it was valuable to review unit conversions. Use Appendix A to assist students in solving the first problem.*
Slide 4 Student Journal Page: 6–3	7) *Display slide 4.* **“Repeat the calculation—this time for an imaginary object that is larger in every dimension and whose mass and volume is ten times larger.”** *Determine how many “ant feet” it would take for this imaginary object to remain adhered to the ceiling. Compare and discuss the difference between the two calculations in class. See Appendix A for calculations.* <u>Teacher Demonstration:</u> *Optional: One pilot teacher added a calculation for a two-ton elephant as well. Actual weight for an African male elephant in Newtons is 122,580 Newtons. Refer to optional notes in Slide 5.*
Slide 5 Student Journal Pages: 6–3 6–4	**“Let’s return our attention to the gecko.** **Repeat your calculations from the imaginary animal for the Tokay Gecko, which has an average weight of 2.2 Newtons.”** 8) *Have students write a statement and/or draw pictures that describe the relationship between size (mass) and weight and, therefore, the adhesive forces required for an animal to remain on a ceiling.*
Slide 6	9) *Explain to students that they will be using the following terms in this lesson.* **“Adhere describes how something sticks to something else.** **Separation force is the amount of pull that is required to detach two objects.”**
Slide 7	**“What are the tools that we can use in the laboratory to measure the amount of force that an object exerts? What are the units used when measuring with this tool?”** *Forces can be measured with a spring scale that changes when a force is applied. Forces are measured in Newtons (N).*
Slide 8 Student Journal Page:	**“As you have observed a gecko adhering to a wall, you may have wondered about the types of surfaces that are required to accomplish this feat.** **Can the gecko adhere to any surface?** **Does the surface need to be clean or can the gecko adhere to dirty surfaces too?**

6–4	**What if the surface is wet? Will that affect how well the gecko can adhere?** **To better understand how the gecko can adhere to different surfaces, we will be exploring the forces involved in the adhesion of transparent tape on a table top."** 10) *Tell students that over the next day or so, they will be able to refine this question based on how they set up their experiment.* 11) *Prior to showing slide 9 introduce the Tape Pull activity by having the students answer the question in their journal on page 6–4.*
Slide 9 Student Journal Pages: 6–5 6–6	**"You will be working with transparent tape on the tabletop and measuring the force required to remove the tape with different amounts of dirt. This force, as stated previously, is actually GREATER THAN the adhesive force."** 12) *Before beginning the experiment have students work with the materials and practice the tape pull procedure as described on Student Journal page 6–5.* **"Write down the independent variable (manipulated variable) and the dependent variable (responding variable)."** *Allow students to identify the amount of dirt as the independent variable and the force that it takes to remove or break the adhesion as the dependent variable.* *Optional: Use the "sticky hands" toy (the one that initially sticks to glass then slowly falls/rolls down the glass) as a demonstration of dirt's effect. This toy's ability to stick decreases rapidly when it becomes dirty.* 13) *Hold a discussion about how to vary the "amount of dirt." For starters, students could test fresh (never before used) tape. Then, rather than adding dirt to the tape, students could make a finger print on the tape and test its adhesion. Other ideas: drop chalk dust onto tape and blow it off, touch the tape to the floor, etc. This then becomes the operational definition for the independent variable.* 14) *Hold a class discussion about how to keep certain variables constant, such as the amount of surface area in which there is contact between surfaces and the angle of pull. Based on this discussion, students should write a research question and a hypothesis before completing the activity. An example of a research question is given on this slide.*
Slide 10 Student Journal Pages: 6–6	**"On this slide, you see how the materials are set up for the experiment. Image 6.8 shows a piece of tape on a table. The end of the tape that is pulled is reinforced with some electrical tape that has a hole punched through it. The hook end of the spring scale is then placed through the hole. Image 6.9 shows the spring scale being pulled at an angle (make sure this is the same each time). During the pull, a second student should carefully observe the force readings on the spring scale."**

6–7 6–8 6–9 	*15) Allow students time to complete the activity as shown in the journal. As students are completing the procedure, make sure they refine their initial question and use their findings in order to provide explanations and further questions.* *Student Journal pages 6–5 through 6–8 can be completed for homework and graded for use as a formative assessment.* *Classroom Management Tip: One pilot teacher assigned jobs for the experiment:* • *Tape handler and assembly* • *Measurer* • *Equipment Manager* *16) After students are done with the experiment, have them answer the questions in their journal on page 6–9 and 6–10.* Question 7: Describe how you made your observations in today's lesson. **a. "What tools did you use?"** (*spring scale)* **b. "Were your observations at the visible or invisible scale?"** (*invisible)* **c. "What is the dominant force at this scale?"** (*adhesive force/unknown)*
Slide 11	**"What do you know about the effectiveness of transparent tape underwater, and how tape gets dirty over time? (***Display slide 11***) This is a quote from researcher Kellar Autumn, Assistant Professor of biology at Lewis & Clark College, about the self-cleaning ability of the gecko."** *Students may state that when transparent tape is placed underwater, it will eventually lose its adhesiveness. Likewise, transparent tape does not work well on dirty surfaces.* *17) It should be noted that ants leave a residue behind as they walk, whereas geckos do not.* *18) Draw students' attention to the note on the slide about the gecko adhesion working underwater.* *Optional: Students could test other variables: amount of tape contact area, cleanliness of the surface, etc.*
Slide 12	*19) As a culminating class discussion, ask students to respond to the questions in "Making Connections."* **"Let's review.** **1. Describe one or two ideas that you learned during this lesson.** **2. What factors contribute to the amount of force to remove a sticky substance?** **3. How does dirt affect adhesion?** **4. Do you think that a sticky substance is a possible method for the gecko adhesion?**

	5. How do you think the gecko sticks to the ceiling? **6. What should we explore next?"**
Slide 13	*20) The pilot-test teachers highly recommend using this flow chart at the end and/or beginning of each lesson. The end of each lesson contains this flow chart that provides an opportunity to show students the "big picture" and where they are in the lesson sequence. The following color code is used:* *Yellow: Past Lessons* *Blue: Current Lesson* *Green: Next Lesson* *White: Future Lesson*

Appendix A: Calculations and Possible Responses to Accompany PowerPoint Slides

Slide 3 Calculations
Ant
Weight of Ant = 0.00004 Newtons or 4×10^{-5} Newtons
Weight of Ant/6 Ant Feet = Force for each foot = 0.0000067 Newtons per Ant Foot or 6.7×10^{-6} Newtons per Ant Foot

Slide 4 Calculations
Ant Mass Times 10 times what it was before
Then IF the Ant Foot can ONLY support 6.7×10^{-6} N, how many ant feet would be required?
Weight of Imaginary object / Force for each Ant Foot
4×10^{-4} Newtons/6.7×10^{-6} Newtons per Ant Foot
59.7 ant feet = 60 ant feet

Slide 5 Calculations
Gecko
Weight of Gecko = 2.2 Newtons
2.2 Newtons/6.7×10^{-6} Newtons per Ant Foot
328,358 ant feet

From Liang, Autumn, Hsieh, Zesch, Chan, Fearing, Full, Kenny[1]:
43.4 N average sustained clinging force of gecko with 227.1 mm^2 pad area

[1] Autumn, K., Liang, Y. A., Hsieh, S. T., Zesch, W., Chan, W. P., Kenny, T. W., Fearing, R., & Full, R. J. (2000). Adhesive force of a single gecko foot-hair. *Nature*, 405, 681-684.

Slide 5 Calculations (Optional)
200 lb adult
Weight of adult in Newtons = 888.9 Newtons
888.9 Newtons/6.7 X 10^{-6} Newtons per Ant Foot
132,671,642 ant feet

27,000 lb African male elephant
Weight of elephant in Newtons = 122,580 Newtons
122,580 Newtons/6.7 x 10^{-6} Newtons per Ant Foot
18,295,522,390 ant feet

Appendix B: NanoLeap Physical Science Vocabulary for Lesson 6

Adhere
1. To hold fast or to stick
2. To bind to

Adhesive
A substance that helps objects stick together

Balanced Forces
For each force acting on a body, there is another force on the same body equal in magnitude and opposite in direction. A body is said to be at rest if it is being acted on by balanced forces.

Dependent Variable
A factor or condition that might be affected as a result of a change in the independent variable (also called a responding variable)

Force
1. Energy exerted
2. A push or a pull that acts on an object

Independent Variable
A factor or condition that is intentionally changed by an investigator or experiment to explore its effects on other factors (also called a manipulated variable)

Mass
1. A quantity of matter
2. A measurement of the quantity

Net Force
The resultant non-zero force due to an unbalanced force

Newton
A unit of force needed to change the speed of a kilogram of mass by one meter per second for every second that the force is acting on the mass

Unbalanced Force
When there is an individual force that is not being balanced by a force of equal magnitude and in the opposite direction. A body is said to be in motion if acted upon by unbalanced forces.

Volume
The amount of space occupied by a three-dimensional object (Length times Width times Height for a rectangular object)