A Sticky Situation: A suite of lessons on adhesives for the STEM Acoustic Guitar Grant

A Sticky Situation: The Chemistry of Glues. Selecting the Best Glue for Acoustic Guitar Applications

Debbie French, PhD

Wilkes University

[Frenchd14@yahoo.com](mailto:Frenchd14@yahoo.com)

Overview: This suite of lessons contains several adhesive-themed activities that may be used together or separately, and can be easily modified for a variety of grade levels. Lessons included in this suite are:

|  |  |
| --- | --- |
| A Sticky Situation | |
| Sticking to History | Students research adhesives and create a timeline of adhesive developments and their uses. |
| A Sticky Situation: Types of Adhesives with Applications to Acoustic Guitars | Direct instruction on the main types of glues; students create a graphic organizer based on this information. |
| Visualizing Viscosity of Glues | In this teacher-led demonstration, glue of different types is placed on a board and tilted at an angle. Students get to see which type of glue has the highest/least viscosity. |
| Strength that Sticks | Students test different glues to determine the strength of the glue. |
| Sticky Scenarios | Students apply their knowledge of glue to different guitar building situations. |
| How does the type of Glue affect the sound of a guitar? | <https://www.taylorguitars.com/videos/craftsmanship/new-800-series-guitar-glue/85726818-90452002/> |

Chemistry of Adhesives

**Description of Activity**

* General description of activity.

**Learning Objectives:**

1. Students will
2. Students will
3. Students will

**Standards:**

Next Generation Science Standards (NGSS):

|  |  |  |
| --- | --- | --- |
| Student Performance Expectation: HS-PS2-6 | Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. | |
| Science And Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
| Obtaining, Evaluating and Communicating information | PS1.A: Structure & Properties of Matter  The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. | **Structure & Function**  Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. |

Common Core ELA Standards:

**RST.11-12.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or

inconsistencies in the account.

**HSN-Q.A.1:** Common Core Math Standards: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and

interpret the scale and the origin in graphs and data displays.

**Materials Required:**

* Accompanying PowerPoint Lecture
* ChemMatters article, “A Sticky Situation” [optional]

**Safety:**

**safetys:**

* List any safety equipment needed and discuss any safety concerns here.

**References:**

* Shiber, L. (2006). A sticky situation. ChemMatters. https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/articlesbytopic/bonding/chemmatters-dec2006-glue.pdf

**Activity:**

* Write the activity as you would give it out to students. Please include an answer key, if appropriate.

**Quiz:**

* Include at least 10 quiz questions with answer key. (Questions must be Multiple Choice, and/or Matching).

**Reviewing Faculty Cohort Members:**

* Include at least two names and schools of reviewing faculty cohort members (refer to email list for faculty cohort member email addresses).

**A Sticky Situation: Types of Adhesives with Applications to Acoustic Guitars—Student Handout**

Introduction:

* What types of glues have you used before?
* How have you used them?
* List and describe three ways glues are used in the construction of an acoustic guitar.

1.

2.

3.

Purpose:

* Throughout this unit, we are going to learn about the different types of adhesives that are used in the construction of an acoustic guitar.
* We are also going to experiment with different types of glue to determine some of their properties such as viscosity and strength.

|  |  |  |  |
| --- | --- | --- | --- |
| Polyvinyl Acetate (PVA) | | | |
| About: | | General Uses: | |
| * The most common variety of PVA glue is white \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ glue. * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ glue is another type of PVA \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and is yellow in appearance.   + It has slightly different \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ than school glue.   + Wood glue dries \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and is not as affected by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. | | * PVA glues are widely used in a variety of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ applications. | |
| Pros: | | Cons: | |
| * Easily \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ -based * Non-\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | * Sensitive to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ /humidity * Works by being absorbed by the two \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. These surfaces become bonded as water in the glue \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. Works only on \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ materials such as paper, cardboard, and wood. | |
| Guitar Uses: | | | |
| * While the traditional white school glue is not used in the construction of the acoustic guitar, wood glue is used in several applications:   + Gluing the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ onto the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_   + Gluing the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ onto the top/bottom of guitar body   + Gluing the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ around the perimeter of the top/bottom of guitar   + Gluing the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to the top of the guitar | | | |
| Dry Time | | | |
| Instantly | Hours | | 1 Day + |

|  |  |  |  |
| --- | --- | --- | --- |
| Animal-Based Glues (Hide Glues) | | | |
| About: | | General Uses: | |
| * Animal-based glues come in several types:   + Casein glues are made from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_   + Fish glue is made from fish bones and scales and dries \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_   + Hide glues are made from animal hide, collagen, bone, and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ tissues   + Some glues have been made from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | * Have been used to bind \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ together to form \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * Fish glues are used on the back of adhesive \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (plant-based glues have also been used on stamps) | |
| Pros: | | Cons: | |
| * Strong * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ —when heated the glue joint releases. This is useful for making repairs. * Glue will not move when under tension (called “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_”). * Does not hinder sound \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | * Is usable within a narrow \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ range (~50◦C, or 120 ◦F) * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (may be an advantage to break off a component to repair) * Glue joints are sensitive to extreme \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ changes and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ changes—may affect transportation and use of instrument | |
| Guitar Uses: | | | |
| * Hide glues were the primary glues used by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and other instrument makers for centuries * Used to attach the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ onto the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (this may be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ for repairs) * Fish glues are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and are used on instruments where glue joints may be visible | | | |
| Dry Time | | | |
| Instantly | Hours | | 1 Day + |

|  |  |  |  |
| --- | --- | --- | --- |
| Cyanoacrylate Glues (CA) “Super Glue” | | | |
| About: | | General Uses: | |
|  | |  | |
| Pros: | | Cons: | |
| * Quick \_\_\_\_\_\_\_\_\_\_\_\_time (though some CA glues are designed to dry longer) * Dries \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * Glue joint can come apart under \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ irritant * May \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ instantly to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | |
| Guitar Uses: | | | |
| * Low-\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ superglues can fill \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (can mix with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ so the blemish cannot be seen) * CA glue can be used to hold \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in the fret slot, if the fret will not “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_” properly | | | |
| Dry Time | | | |
| Instantly | Hours | | 1 Day + |

|  |  |  |  |
| --- | --- | --- | --- |
| Two-part (Catalyst) Glues—Epoxy | | | |
| About: | | General Uses: | |
| * Epoxies are made by combining two \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_: epoxide \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ compound, which \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the material. | | * Epoxy glue is used where a strong bond is required. Epoxy is used in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ industry. | |
| Pros: | | Cons: | |
| * Glues in the epoxy family produce a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ hold. * Epoxy-based finishes are \_\_\_\_\_\_-cured and take only \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to cure. They produce a hard, high-gloss finish. | | * The two chemicals required to make epoxy must be mixed \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to using. Any unused epoxy cannot be stored and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ at a later time. * Epoxy-based \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ may be used on guitars. | |
| Guitar Uses: | | | |
| * Epoxies are not widely used in the construction of acoustic guitars. * However, they may be used to glue \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in-lays in the wood. * Some epoxies may be used as a guitar \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. | | | |
| Dry Time | | | |
| Instantly | Hours | | 1 Day + |

**How glues work**

There are three primary mechanisms for how glues bond materials together:

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Joints
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Theory
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bonds (Interfacial Secondary Bonds)

How glues work: Mechanical Joints

* Some glues act like “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ™.” Velcro™ features one piece of material with “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_” that attaches to another piece of material with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Some glues may behave in a similar way by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ joining the two \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* The \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the surface, the more surface \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is exposed, and therefore, the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the bond.

How glues work: Diffusion Theory

* Some glues work by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ reacting to the two surfaces (in this case, usually \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_), by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, or breaking down the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ between those surfaces.
* These surfaces \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ together, and when the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ solvent \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, the glue “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_,” which bonds the two surfaces together.
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ glue for plastic models is an example of this.

How glues work: Interfacial Secondary Bonds

* The third way in which glues work features \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bonding between two materials.
* Such chemical bonds include \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bonding or through \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ forces.
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bonding produces a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ hold
* van der Waals bonding can produce quite a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ hold.
* van der Waals forces occur in glues such as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ glues, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (school glue) and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and is used to bond materials such as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ , and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

**Visualizing Viscosity of Glues**

In this teacher-led demonstration, students will get to see how each type of glue has a different viscosity.

Definitions:

You may wish to review the definition of viscosity with your students before you begin the demonstration.

**Viscosity:** A fluid’s resistant to flow. Ketchup is a classic example of a fluid with a high viscosity. Your students may have had to [patiently] wait for ketchup to come out of a glass jar. That is due to its high viscosity. Depending on the situation, viscosity may be a desirable property (or not!). During your acoustic guitar build, glues of different viscosities will be used at different times. For example, thin super glue is useful for gluing in frets—the glue seeps under the fret in the fret slot.

Materials:

* Board
* Waxed paper or parchment paper (to protect board so that it can be re-used)
* Different types of glue. For this demonstration, Elmer’s glue, Titebond I, Titebond II, and Titebond III were used.

Resources:

* A good simulation of liquids of different viscosities can be found at:

<https://en.wikipedia.org/wiki/Viscosity>

Directions:

1. Ask students to predict which type of glue will run down the board the most (or the fastest).
2. Label the waxed paper with the names of the glue you will be using.
3. Place a drop of glue at the “start” line on the board.
4. Tilt the board at an angle so that the glue starts to run.
5. Have students record the results of the test and compare this to their prediction in Step 1.
6. Lead the class in a discussion about why glues come in different viscosities. What are the pros and cons?

**Visualizing Viscosity of Glues—Student Handout**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| Purpose |  |

**Before the Demonstration:**

|  |  |  |
| --- | --- | --- |
|  | Definition | Examples |
| Viscosity |  |  |

1. Before your teacher does the demonstration, predict which glues will flow *fastest* to *slowest*:

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. What happened? Write down which glues flowed *fastest* to *slowest*.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. Rank the glues listed above in #3 according to *highest viscosity* to *lowest viscosity.*

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. Which glue had the *highest viscosity?*

5. Which glue had the *lowest viscosity?*

6. How are *viscosity* and *velocity* of a fluid’s flow rate related?

7. How would you describe viscosity to someone who has never heard the word before?

**Visualizing Viscosity of Glues—Student Handout**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| **Purpose** | **The purposes of this activity are**   1. **To rank different types of glue according to their viscosity** 2. **Determine a relationship between viscosity and velocity.** |

**Before the Demonstration:**

|  |  |  |
| --- | --- | --- |
|  | Definition | Examples |
| Viscosity | **A fluid’s resistance to flow.** | **Ketchup has a high viscosity.**  **Water has a low viscosity.** |

1. Before your teacher does the demonstration, predict which glues will flow *fastest* to *slowest*:

Answers will vary.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. What happened? Write down which glues flowed *fastest* to *slowest*?

Answers will vary based on which glues were used in this demonstration.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. Rank the glues listed above in #3 according to *highest viscosity* to *lowest viscosity.*

Answers will vary.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. Which glue had the *highest viscosity?* Answers will vary.

5. Which glue had the *lowest viscosity?* Answers will vary.

6. How are *viscosity* and *velocity* of a fluid’s flow rate related? **Viscosity and a fluid’s flow rate are inversely related. As viscosity increases, the fluid flows more slowly.**

7. How would you describe viscosity to someone who has never heard the word before?

**Viscosity is a fluid’s resistance to flow. Thicker liquids like maple syrup and ketchup have a high viscosity, meaning they flow slowly. Thinner liquids like water flow more quickly and they have a lower viscosity.**

**Strength that Sticks**

**Purpose:**

The purpose of this activity is for students to explore factors that affect the strength of glue. Students will first determine which type of glue is the strongest (holds the most mass). Students will then extend their knowledge

**Materials:**

**Per group:**

* Two wooden craft sticks
* Ruler
* C-clamp to hold samples to the table
* Small clamps to hold samples together (for Extension #4)
* Metal washers or pennies
* Cardboard box
* Safety goggles
* Metal can with handle (watch for sharp edges)
* Variety of glues (School glue, different types of wood glues, Superglue\*

\**Safety note: Superglue is a skin and eye irritant. Superglue may instantly bond skin to skin or skin to other objects. Use only with close supervision of students. Alternatively, the teacher may wish to prepare this sample.*

MSDS Sheet for Superglue:

<https://www.gorillatough.com/wp-content/uploads/Gorilla-Super-Glue-2.pdf>

**Per class:**

* Balance or scale

Samples per group:

Wood glue should be used for each activity. You may also wish to use school glue, super glue, of other wood glues. Wood glue should only be used for the Extension activities. Due to the dry time, you may wish to make the samples before class.

**Strength that Sticks**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Background:** An acoustic guitar has many glue joints and must withstand the tension from the six strings. The tension due to strings is around 460 N. In this activity, you will be investigating how much mass four types of glue will hold. You will then convert the mass in grams to the weight in Newtons. Finally, as an extension, you will place another set of four samples in the freezer to mimic what would happen if you left your guitar in your car during cold weather.

|  |  |
| --- | --- |
| **Purpose** |  |

**Record your results in a table:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Glue #1: | Glue #2: | Glue #3: | Glue #4: |
| Maximum mass sample will hold (g) |  |  |  |  |
| Weight (Newtons) |  |  |  |  |

**Extension #1:**

We will repeat the experiment from above just using the wood glue. However, instead of putting glue all over the craft stick, just run a thin line of glue down the middle of the craft stick and let dry. On another set of craft sticks, put a smooth coat of wood glue all over the surface, but just let dry 7 minutes.

|  |  |  |
| --- | --- | --- |
|  | Wood glue with thin line of glue | Wood glue that has only dried 7 minutes |
| Maximum mass sample will hold (g) |  |  |
| Weight (Newtons) |  |  |

Describe what happened to the samples from Extension #1:

Why is it important to apply an even coating of glue to the surface?

**Extension #2: Winter Jam**

You and your band members are playing a gig in the winter and the temperature is 0°F. You and your band members stop at a restaurant to grab a bit to eat before your performance. You all leave your acoustic guitars in the car while you eat. Predict what could happen to the glue joints on your guitar:

**Test:**

Create another set of samples and place these samples in the freezer (0°F) for 15 minutes (after the glue has cured for 15 minutes). Take the frozen samples out and perform the test again. Record your results in the following table:

**Record your results in a table:**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Glue #1: | Glue #2: | Glue #3: |
| Maximum mass sample will hold (g) |  |  |  |
| Weight (Newtons) |  |  |  |

How do your answers compare to the first trial?

**Extension #3: Heat it up!**

You and your band members are playing a gig in the summer in North Carolina where the temperature is 90°F. You and your band members stop at a restaurant to grab a bit to eat before your performance. You all leave your acoustic guitars in the car while you eat. Predict what could happen to the glue joints on your guitar:

**Test:**

Create another set of samples and expose these samples to heat (either using a hair drier or a heat gun) (after the glue has cured for 15 minutes). Perform the test again after the samples have been heated. Record your results in the following table:

**Record your results in a table:**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Glue #1: | Glue #2: | Glue #3: |
| Maximum mass sample will hold (g) |  |  |  |
| Weight (Newtons) |  |  |  |

How do your answers compare to the first trial?

**Extension #4:**

You will only be using wood glue for this activity. First, create a sample set of craft sticks joined together by a properly made glue joint—one that has glue evenly spread across the surface. Second, join two craft sticks together using a starved glue joint by just running a bead of glue down one craft stick where they overlap. Finally, create another sample with a proper glue joint, but clamp the sample using a small clamp. Wait 15 minutes for these samples to dry, then begin testing.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Wood glue—proper glue joint, unclamped | Wood glue—starved glue joint | Wood glue—proper glue joint, clamped |
| Maximum mass sample will hold (g) |  |  |  |
| Weight (Newtons) |  |  |  |

Describe your results below:

Describe your results below:

**Sticky Scenarios**

**Purpose:**

The scenarios activity may be used as a summative assessment for students. There are four scenarios. Scenarios 1 and 2 are at an intermediate level, while Scenarios 3 and 4 are more advanced and require a bit more research.

**Materials:**

**-**Printed Scenarios (one scenario provided per group

-Internet access for research

-Assortment of craft sticks, plastic knives, glues, clamps for students to conduct experimental testing.

**Student Handouts**

|  |
| --- |
| Scenario 1  To: Research Team #1  From: Mile-high Music Studios  Re: Air transport of acoustic guitars  We understand that your research team has extensive experience working with adhesives that can withstand drastic temperature changes.  We would like you and your team to research wood glues that would work well for acoustic guitars, but will not fail in extreme temperature changes. The guitars will be stowed in the cargo hold. Please indicate what lowest temperature would be expected in flight as well as the highest temperature the guitar may be subjected to when the plane is sitting on the tarmac in Phoenix, Az.  Please submit the following:  -Experimental data on the effects of how much force wood can withstand in extreme temperature changes  -A recommendation for a suitable glue for our company to use |

|  |
| --- |
| Scenario 2  To: Research Team #2  From: Carbon Rocks, LLC  Re: Adhesive needed for a hybrid guitar body  We understand that your research team has extensive experience working with adhesives that can adhere different materials. Our company is looking to create a guitar with a carbon-fiber body and a spruce top. However, our R & D department has been unsuccessful thus far finding a suitable glue to join the two materials. We would like you and your research team to investigate which type of glue would be best suited for this task.  Please submit the following:  -Experimental data on which glue joined the two materials (wood and plastic) together and held the most weight.  -A recommendation for which type of glue we should use. |

|  |
| --- |
| Scenario 3  To: Research Team #3  From: Silicone-based Guitar Forms, LLC  Re: Glues not adhering to a Silicone finish?  We are reaching out to your research group in hopes you can help us with a problem. In addition to our retail stores, we have opened up guitar repair shops. However, our luthiers are experiencing many issues with our regular guitar glue not adhering to guitar finishes. We are hoping you can use your chemistry knowledge to help us figure out this issue.  Please submit the following:  -An experiment showing what happens to glue when it is applied to a surface treated with silicone polish  -Explain the chemistry behind what is happening  -How to fix that problem |

|  |
| --- |
| Scenario 4  To: Research Team #4  From: Clarity Guitars  Re: High-Pressure Laminated Guitars  We understand that you and your team have experience working with high-pressure laminates (HPL). Our competitor (<https://hazeguitars.com/blog/what-you-should-know-about-high-pressure-laminate-hpl-guitars)> has produced an HPL guitar and we are looking into developing a competing model. However, we have only ever worked with traditional tone woods, which is why we are seeking the advice of your research group.  Please submit the following:  -Experimental data showing the different strengths of regular wood strips vs. laminated wood strips glued together (uncompressed) and glued together (compressed).  -Your group’s recommendation for whether we should pursue creating a competing model using HPL based on your data. |