How Sweet It Is!
A Study of Viscosity

Science TEKS:

(1) Scientific processes. The student, for at least 40% of instructional time, conducts field and laboratory investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:
(A) demonstrate safe practices during field and laboratory investigations; and
(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:
(A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;
(B) collect data and make measurements with precision;
(C) organize, analyze, evaluate, make inferences, and predict trends from data;
(D) communicate valid conclusions.
(7) Science concepts. The student knows relationships exist between properties of matter and its components. The student is expected to:
(A) investigate and identify properties of fluids including density, viscosity, and buoyancy;

Science 10^{th} grade TAKS:
Objective 1: The student will demonstrate an understanding of the nature of science.
Objective 4: The student will demonstrate an understanding of the structures and properties of matter.

Science 11^{th} grade TAKS:
Objective 1: The student will demonstrate an understanding of the nature of science.
Objective 4: The student will demonstrate an understanding of the structures and properties of matter.

Algebra TEKS:
(b)(1)(A) The student describes independent and dependent quantities in functional relationships.
(b)(1)(B) The student gathers and records data, or uses data sets, to determine functional (systematic) relationships between quantities.
(b)(1)(C) The student describes functional relationships for given problem situations and writes equations or inequalities to answer questions arising from the situations.
(b)(1)D) The student represents relationships among quantities using concrete models, tables, graphs, diagrams, verbal descriptions, equations, and inequalities.

(b)(1)(E) The student interprets and makes inferences from functional relationships.

(b)(2) (B) For a variety of situations, the student identifies the mathematical domains and ranges and determines reasonable domain and range values for given situations.
(b)(2)(C) The student interprets situations in of given graphs or creates situations that fit given graphs.
(b)(2)(D) In solving problems, the student collects and organizes data, makes and interprets scatter plots, and models, and makes decisions and critical judgments.
(b)(3)(B) Given situations, the student looks for patterns and represents generalizations algebraically.
(c)(1)(A) The student determines whether or not given situations can be represented by linear functions.
(c)(1)(B) The student determines the domain and range values for which linear functions make sense for given situations.
(c)(1)(C) The student translates among and uses algebraic, tabular, graphical, or verbal descriptions of linear functions.
(c)(2)(A) The student develops the concept of slope as rate of change and determines slopes from graphs, tables, and algebraic representations.
(c)(2)(B) The student interprets the meaning of slope and intercepts in situations using data, symbolic representations, or.
(c)(2)(C) The student investigates, describes, and predicts the effects of changes in and b on the graph of $y = mx + b$.
(c)(2)(E) The student determines the intercepts of linear functions from graphs, tables, and algebraic representations.
(c)(2)(G) The student relates direct variation to linear functions and solves problems involving proportional change.
(c)(3)(A) The student analyzes situations involving linear functions and formulates linear equations or inequalities to solve problems.
(c)(3)(B) The student investigates methods for solving linear equations and inequalities using concrete models , and the properties of equality, selects a method, and solves the equations and inequalities.
(c)(3)(C) For given contexts, the student interprets and determines the reasonableness of solutions to linear equations and inequalities.
(c)(4)(A) The student analyzes situations and formulates systems of linear equations to solve problems.
(c)(4)(B) The student solves systems of linear equations using concrete models, graphs, tables, and algebraic methods.
(c)(4)(C) For given contexts, the student interprets and determines the reasonableness of solutions to systems of linear equations.

11 th grade Mathematics TAKS
2A(b)(4)(A) The student finds specific function values, simplifies polynomial expressions, transforms and solves equations, and factors as necessary in problem situations.

2A(b)(4)(B) The student uses the commutative, associative, and distributive properties to simplify algebraic expressions.
3A(c)(1)(A) The student determines whether or not given situations can be represented by linear functions
3A(c)(1) (C) The student translates among and uses algebraic, tabular, graphical, or verbal descriptions of linear functions.
3A(c)(2) (A) The student develops the concept of slope as rate of change and determines slopes from graphs, tables, and algebraic representations.
3A(c)(2)(B) The student interprets the meaning of slope and intercepts in situations using data, symbolic representations, or graphs.
3A(c)(2)(C) The student investigates, describes, and predicts the effects of changes in m and b on the graph of $y = mx + b$.
3A(c)(2)(D) The student graphs and writes equations of lines given characteristics such as two points, a point and a slope, or a slope and y-intercept.
3A(c)(2)(E) The student determines the intercepts of linear functions from graphs, tables, and algebraic representations.
3A(c)(2)(F) The student interprets and predicts the effects of changing slope and y-intercept in applied situations.
3A(c)(2)(G) The student relates direct variation to linear functions and solves problems involving proportional change.
4A(c)(3)(A) The student analyzes situations involving linear functions and formulates linear equations or inequalities to solve problems.
4A(c)(3)(B) The student investigates methods for solving linear equations and inequalities using [concrete] models, graphs, and the properties of equality, selects a method, and solves. The equations and inequalities.
4A(c)(3)(C) For given contexts, the student interprets and determines the reasonableness of solutions to linear equations and inequalities.
4A(c)(4)(A) The student analyzes situations and formulates systems of linear equations to solve problems.
4A(c)(4)(B) The student solves systems of linear equations using [concrete] models, graphs, tables, and algebraic methods.
4A(c)(4)(C) For given contexts, the student interprets and determines the reasonableness of solutions to systems of linear equations.
9(8.13)(B) Recognize misuses of graphical or numerical information and evaluate predictions and conclusions based on data analysis.

Student Objective:

Students investigate the scientific and algebraic principles associated with various objects and their viscosities. Students will investigate to collect qualitative and quantitative data, create appropriate graphical representations, determine trend lines, derive reasonable equations, calculate and predict viscosities of syrup at various temperatures.

Background Information:

Viscosity is a characteristic of fluids that describes its resistance to flow. Viscosity decreases as heat is applied by about 2% per degree C and increases as the liquid or gas is cooled or pressure is applied.

There are many examples of viscosity that we see in the real world. Oil well drilling rigs use a drilling fluid commonly called "mud" to circulate during the drilling process. One of the properties of the "mud" that is constantly monitored is the viscosity. A worker will test it periodically by timing how long it takes to run out of a funnel-like device. Water is added to reduce the viscosity and various chemicals are added to increase the viscosity.

Viscosity is very important in the study of volcanoes. The viscosity of magma is related to temperature. Higher temperature magma has a lower viscosity than that with a lower temperature. Magma that has a lower viscosity tends to allow gas bubbles to move freely and escape easily. A more viscous magma tends to trap the gases and allow them to build up. Thus low viscosity magma tends to produce lava flows while magma with a high viscosity often produces explosive eruptions. A volcano's shape is also related to the viscosity of the lava. Low viscosity lava is able to travel farther from the vent, producing shield volcanoes like those in Hawaii. Higher viscosity lava does not travel as far, producing volcanic domes such as the one inside Mount St. Helens.

There are many types of viscometers, one type of viscometer used to determine viscosity is to drop a sphere into the liquid or gas. This is the type that will be used for the following investigations.

The following equation is one used to determine viscosity by scientists and engineers. This equation is complex and will not be used in this investigation. It is presented only for teacher background knowledge. Simply measuring the time needed for the sphere to fall through the liquid will give a good representation of viscosity for students.

$$\text{viscosity} = \eta = \frac{2(\Delta p) g a^2}{9v}$$

Δp = difference in density between the sphere and the liquid

g = acceleration of gravity

a = radius of sphere

v = velocity = d/t = (distance sphere falls)/(time of it takes to fall)

Viscosity calculated using this equation is measured in units of Pa•s (Pascal•seconds) or poise, depending on whether the m-kg-s system or the cm-g-s system is used.

Engage:
Show the students two empty test tubes and fill each with syrup from the same container. Have two styrofoam cups previously filled, one with hot water and the other with cold water. Place one test tube in each cup and leave undisturbed for a few minutes. Pull the tubes from the water baths and pour out the syrup. Allow students to discuss their observations and brainstorm possible explanations. Ask probing questions as needed

Possible questions:

What do you notice about the liquid in the test tubes?
What might cause this?
Is there anything unusual about the set up?
How did I start the demonstration?
What other information might you need?
How could you test your ideas?

Part 1:
Record your answe rs on your Preliminary Investigation Result Sheet.

Have you ever kept syrup in a refrigerator? Describe the behavior of the syrup when it is very cold.

The syrup gets thicker (more viscous) when it is cold.

What happens when the syrup begins to warm up?

It begins to flow faster, is less thick (viscous).

Viscosity describes the "thickness", or resistance to flow of a fluid. A fluid with a low viscosity will flow easily, while one with a high viscosity will not. Water would have a low viscosity, while syrup would have a higher one.

Viscosity is often measured by the time it takes for a fluid to flow through a hole of some kind. Another method could be to time how long it takes an object to fall through the liquid.

Do you think that viscosity is related to temperature? Sketch what you think a graph of viscosity vs. temperature would look like on your results sheet and justify your answer.

Exploration

Investigation1:

What happens to an object's viscosity as the temperature changes?

Suggested Materials:

- **Corn syrup**
- **several medium sized test tubes**
- **BB's**
- **stopwatch**
- **styrofoam cups**
- **ice**
- **a source of hot water** (an electric tea kettle is a fast and easy source)
- **TI 83+ calculator, CBL 2 and Temperature Probe (or a thermometer)**

Discuss with your group the task assigned. Develop a plan to experimentally determine what effect temperature has on viscosity of syrup. You will measure viscosity by timing how long it takes for a BB to fall through the syrup. Be sure and let your teacher check your plan before you start.

Depending on the level of experience of your students, you may need to provide assistance in designing the experiment. Review the following directions to familiarize yourself with possible problems with the experiment.

- Gather several test tubes and fill them with equal amounts of corn syrup. Leave a little space at the top of the tube.
- Prepare water baths of different temperatures. Use cups or beakers and produce a different temperature for each tube. You may use combinations of ice, tap water and hot water to create a range of temperatures.
- Place one tube in each bath and leave for several minutes. Be sure and keep the bath at a constant temperature. Also be sure that all of the syrup in the tube is submerged in the bath. Unequal heating or cooling may cause problems.
- After several minutes, the temperature of the syrup should be the same as the bath. Measure the temperature of the bath and quickly remove the tube from the bath.
- Hold the tube perfectly vertical and drop a BB into the syrup. Time how long it takes for the BB to fall to the bottom of the tube. Wait until the BB breaks through the surface layer and actually begins falling through the syrup before you begin timing. Repeat a couple of times before the temperature changes much and average the times.

<u>Pay particular attention to any safety directions given by your teacher.</u>
Be sure and address safety issues with the students, particularly with the hot water and glass. Safety goggles and aprons may also be appropriate. Keep a careful watch on the BB's. They may pose an eye hazard if thrown, or cause falls if they get on the floor.

1. Which will be the independent variable and which will be the dependent variable?

Temperature is independent and Time is dependent

2. Plot a graph of your data. Sketch what your graph looks like on the results sheet. Be sure and label the axes properly. Describe in your own words what the graph tells you. Comment on how the actual graph compares to your prediction.

See results sheet

3. Find a mathematical function that fits the data. Explain the meaning of the function in your own words.

See results sheet

4. Rewrite your function in words, and include all appropriate units .
See results sheet

5. What problems might occur if motor oil behaved the same way that syrup does?

Answers will vary. If the oil is too thick when it is cold, it will not flow properly through the engine, causing potential problems.

6. An old TV commercial for ketchup showed it flowing very slowly. Assuming the ketchup behave like corn syrup, how could you make the ketchup flow faster?

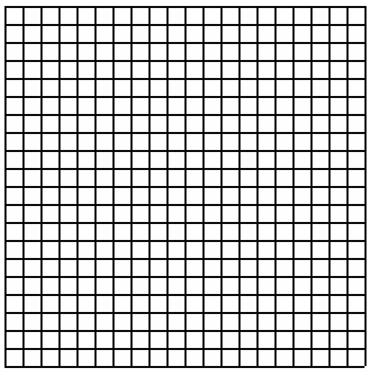
You could warm the ketchup to make it flow faster.

Investigation Results Sheet: Viscosity and Temperature

Independent variable *Temperature*

Dependent variable *Time*

Prediction:



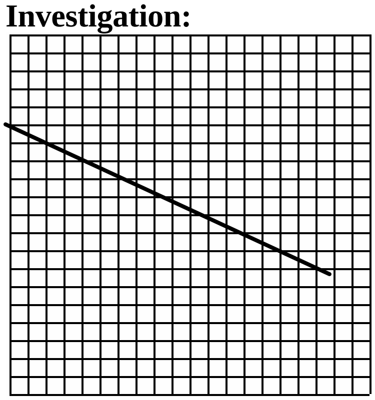
Graph's meaning:

Drawing and explanation will vary. This is only to determine students thinking. There is no right or wrong answer.

Sample data

Temperature (°C)	Time (s)
50	*5.50*
40	*13.2*
30	*20.9*
20	*28.6*
10	*36.3*

Investigation:



Graph's meaning:

Linear with a negative slope. As the temperature increases, the time for the BB to fall through the syrup decreases.

Function and meaning

Typical data might be: y = -0.77x + 44
Time = (-0.77 s/°C) temperature + 44s

Time decreases at a rate of 0.77 seconds per °C increase. The assumption is that at 0 °C, the starting point, that the time would be 44 seconds.

Elaboration

Soda Stuff!

You work for a soda bottling company, and corn syrup is the sweetener used to make your sodas. The syrup is allowed to gravity flow from a large tank to your bottling machines. In order for the syrup to flow at the proper rate, it has been determined that the "BB" viscometer time reading should be 5s. What temperature should you keep the syrup tank in order for the syrup to flow properly. Show all your work and explain your thinking

Time = -0.77 s/°C (temperature) + 44 s
Answer should be approximately 50.6 °C

A variety of methods may be used to solve the problem. Students may solve the algebraic equation, use a table or trace along the graph.

Volcano Viscosity

Viscosity is an important property that is used in the study of volcanoes. Here is some actual data from eruptions of Mauna Loa in Hawaii. It includes the date of the eruption, the location where the measurements were taken and an estimation of the viscosity of the lava at that point. Study the data and discuss the conclusion you draw. Be sure and address how this relates to what you have learned about viscosity.

Date	Location	Viscosity
5/4/42	Edge of cone at vent	3×10^3
1/20/49	0.6 km away from the vent	5×10^3
6/2/50	20 km away from the vent	7×10^3

***the vent is where the lava comes out of the ground**

As the lava moves farther away from the vent, the viscosity increases. This relates to our earlier experiments with syrup. As the temperature decreases the syrup became more viscous. As the lava moved farther away from the vent, it began to cool down and the viscosity would increase.

Evaluation

Sample Assessment

Here is some sample data from a viscosity experiment.

Temperature (°C)	Time (s)
50	4
40	12
30	20
20	28
10	36

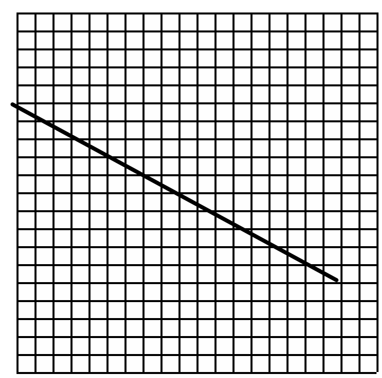
1. **Determine the function that fits this data. Show your work and explain your thinking**

   y = -0.8 x + 44

   Time = (-0.8 s/°C) temperature + 44s

A variety of methods may be used to solve the problem. Students may solve the algebraic equation, use a table or trace along the graph.

2. **Sketch a graph of the data and explain the meaning of the graph.**



Linear with a negative slope. As the temperature increases, the time for the BB to fall through the syrup decreases.
Time decreases at a rate of 0.8 seconds per °C.
The assumption is that at 0 °C, the time would be 44 seconds.

3. **Determine what the time should be if the temperature is 21°C.**

A variety of methods may be used to solve the problem. Students may solve the algebraic equation, use a table or trace along the graph.

27.2 seconds