Viscosity Lesson Plan

Teaching Plan:

Explain how viscosity plays a role in everyday life - Global learning
Explain how viscosity works using user-friendly explanations - Intuitive learning
Introduce the math/physics/chemistry behind it(equations, etc.) - Sensing learning
Activity #1
Activity #2
Activity #3
Close off with some ideas so they can do further research on the topic if they wish

Introduction for Mentees:

If possible, show the Mythbusters clip involving corn starch/water.

So, what is viscosity, and why is it important to engineers? Viscosity is basically a measure of how thick and “sticky” a liquid is. An easy example of this is just how well something pours. Imagine two cups sitting on a tabletop; one holds soda and one holds honey. If a careless person passes by and knocks them over, which cup should you pick up first?

The viscosity of a liquid is determined by a variety of factors, some of which include temperature, the kinds of bonds present, and the stresses applied to the liquid. Most substances tend to decrease in viscosity, or become more fluid, as temperature increases. Imagine melting chocolate, where a solid chunk slowly becomes malleable, eventually becoming a thick liquid. Other substances react strongly to a change in the stresses applied to them. (Talk about Mythbusters clip). In addition, these sorts of qualities have been applied to body armor applications. Some bullet-proof materials are light and flexible when worn, but harden upon impact.

Most commonly, we talk about viscosity in the context of pipe flows, such as the water that that travels from reservoirs into your bathroom. Because of the vast distances of pipe that water flows through in its journey to your house, the ease with which a liquid can be pushed through becomes a huge factor. Say you had to suck honey through a straw; the effort you put in would be analogous to the pumping stations in a water pipeline.

Background for Mentors:

Intuitively, viscosity is the property of a fluid (a liquid or gas) that describes its ability to flow. To roughly determine the viscosity of one fluid relative to another, one can simply pour each fluid from a pitcher, and qualitatively observe the ease with which each fluid exits. For example, honey pours much slower than water, suggesting that honey has a higher viscosity, and thus a greater resistance to flow.

Viscosity arises from the intermolecular forces that take place within a fluid. Different fluids have different intermolecular interactions, so each fluid flows differently. Therefore, from the aforementioned experiment, one can infer that honey has stronger intermolecular interactions than water.

To understand viscosity, it's important to recognize the variables that viscosity depends on. These variables, such as temperature and pressure, affect the intermolecular interactions within a fluid. The temperature dependence of viscosity is perhaps best described by the expression that nothing is "slower than molasses in January." Indeed, the viscosity of a liquid decreases as its temperature increases and increases as its temperature decreases. At lower temperatures the molecules of a liquid interact more with their nearest neighbors, and consequently flow less readily. The opposite is true for molecules at higher temperatures.

To internalize this functional dependence between viscosity and temperature, it is helpful to consider an extremely viscous fluid, such as molten glass. As the temperature of molten glass decreases, it begins to solidify, approaching an "infinite" viscosity, as solid glass, like solid anything else, does not flow. If you proceeded to melt the glass back to its original state, it would begin to flow again due to its now finite viscosity.

Most liquids are considered incompressible, so viscosity is often at most a very weak function of pressure. Pressure is a relevant variable for gases, however, as they are compressible. If you compress a gas, each molecule becomes closer to its nearest neighbors, increasing the overall viscosity of the gas. The temperature dependence of a gas is actually opposite that of a liquid. This can be explained again by nearest neighbors.

An intuitive understanding of viscosity can only get the engineer so far, however. To begin solving most practical problems, viscosity must be both operationally and mathematically defined. Here it is most helpful to consider the general mathematical definition of viscosity:

Viscosity: $\eta = \tau_s / \Gamma_s$

Where τ_s is the shear stress and Γ_s is the shear rate. Therefore, viscosity is the ratio of shear stress to shear rate. Shear stress is a pressure (force/area), and shear rate is a rate(1/time or inverse time), so viscosity is a pressure$\times$time. Some common units are Pa-s and poise. A cool coincidence is that the viscosity of water is about one centipoise!

Shear stress is a force exerted parallel to a surface, rather than perpendicular to it. This can be remembered by noting that when a shear stress is applied to the top of a square, it is deformed to a parallelogram.

A fluid is known as Newtonian if its viscosity is only a function of temperature and pressure (weak), and consequently independent of its shear rate. Gases and most low molecular weight liquids are Newtonian, while high molecular weight liquids are typically non-Newtonian.

Modules/Demos

1) Demonstrate the effect of adding corn starch to water. Ordinary water has a relatively low viscosity and behaves in a way expected of liquids. The addition of corn starch thickens water significantly. We can demonstrate the increase in viscosity by pouring, stirring, or shaking the liquids. We can also add a large amount of corn starch to demonstrate the "walking-on-water" phenomenon. Corn starch/water behaves as a non-Newtonian fluid, where viscosity increases

predictably with the amount of stress applied. As a result, a saturated corn starch/water solution will hold weight for a short time, despite being a liquid.

2) Splash Test: Fill several shallow cups with a variety of liquids with various viscosities. Water, corn starch+water, oil, honey, etc. Drop identical objects from the same height into each of the containers and observe how far and vigorously the liquids splash out of their containers. Ask students to make predictions on which liquids will splash the most, and ask them to tie their predictions to certain other qualities of the liquids we already know. They can also feel the liquids to compare their texture as long as they wash their hands afterwards.

3) Straw Race: Fill several cups with EDIBLE liquids of different viscosities. Water/soda/juice/honey/smoothies/yogurt, etc. This activity will demonstrate the relationship between viscosity and pipe flow. Ask the students to choose a cup and begin drinking their liquid through a straw when you tell them "go." As per the previous demonstration, ask for predictions and their bases for those predictions. Have all the students race, and then ask the fastest/slowest drinkers to compare their efforts when drinking.

Closing Activity and Discussion

Closing activity - Pose a question about how viscosity affects the timing and materials used in operations. Allow room for group discussion amongst the mentees.
Problems engineers are trying to solve today-
Why does cement have to be constantly moving? (because if it is allowed to stopped, it will approach infinite viscosity)
Water mixed with mud can become quite the viscous fluid, which will clog pipes and not allow people to retrieve water for their everyday tasks. People become civil engineers to help with the irrigation.

Materials List
Corn starch
Water bottles
Cups
Water
Oil
Honey
Acetone
Straws
Soda
Juice
Smoothies
Yogurt

Viscosity Worksheet

1) A more viscous fluid such as honey has __________ (stronger/weaker) intermolecular forces compared to a less viscous fluid like water.

2) One way to decrease the viscosity of a *liquid* is to __________ (heat/cool) the fluid.

3) One way to decrease the viscosity of a *gas* is to __________ (heat/cool) the gas.

4) Viscosity is best defined as:

a. Speed x Time
b. Distance x Time
c. Pressure x Time
d. What I had for lunch today

5) Adding corn starch to water __________ (increases/decreases) the overall viscosity

6) More viscous fluids tend to have a __________ (slow/fast) pipe flow

7) Name the type of liquid that you think has the highest viscosity. What properties of the liquid make you think so?

Answers:
1) Stronger
2) Heat
3) Cool
4) c
5) Increases
6) slow
7) honey, starch + water etc.