Rheology and Nanoscale Suspension Behavior

Background:
A "Smart Material" is any material made at the nanoscale level, that performs a specific task when needed. They usually contain mobile electronic charges that can be moved to new positions in the structure by application of a magnetic field, an electric field or by shining a light. The change is similar to a code that is specific to the material. Examples of "smart materials" include tinted automotive glass that responds to sunlight, liquid crystal screens that respond to changes in electric potential or nanoferrofluids that were originally developed by NASA as a way to control the flow of liquid fuels in space. They are now presently used to detect magnetic domains in tapes, computer disks, amorphous alloys, CD/s and microdefects in steel.

Purpose:
The purpose of this activity is to model the use of a nano-sized "smart material" using larger, more familiar compounds, and to demonstrate the ability of nanoferrofuids to detect both flawed and intact magnetic fields.

Materials:

Cornstarch	six, 3 oz. (bathroom-sized) paper cups
Water	small, plastic desert plate or aluminum pie pan
Cooking oil	an apron or painting shirt
Ferrofluid tube	

Graduated cylinder (or measuring spoons will do)
Small vial of ferric and ferrous oxide particles
3 or 4 wooden stirring sticks, popsicle sticks or tongue depressors
Small (about 8 cm) lengths of copper, aluminum, lead, iron or steel, stainless steel, plastic, glass and several magnets of different sizes, shapes and strengths.

Precautions:
The first part of this activity involves mixing, stirring and "grabbing" liquids and pasty mixtures. Everything cleans up nicely and it's fun, but messy.

Procedure A: Dilatant

1. Place about 2 tablespoons (30 mL) of cornstarch, water, and corn oil in each of 3 separate 3 oz. (bathroom-sized) paper cups.

2. Observe the substances and record visual characteristics such as color, state (solid, liquid, powder, etc.) in the space provided in Table I of the data page.

3. Observe the viscosity of the sample by stirring first slowly, then vigorously; by gently lowering the stirring stick down into the substance slowly and then stabbing from the top quickly; and finally by raising the stick out slowly and then pulling it up quickly.

4. Pour each cup out on a separate, small plastic dessert plate to observe flow

characteristics and viscosity. With the wooden stir stick, push the substance from the slides, slowly and then abruptly, and try scooping some from the edge.

5. Record all observations from steps 2-4 in Table I. Did they all behave as you would have predicted?

6. Again measure about 2 tablespoons each of corn oil and water into two separate cups. Add 3 tablespoons of cornstarch to the cup of water (be sure you have them mixed in a 3:2 ratio, cornstarch to water) and 4 tablespoons of cornstarch to the cup of corn oil (a ratio of 2:1 cornstarch to oil).

7. Carefully and very slowly, mix the cornstarch with each liquid using frequent slicing motions from the top through the middle with infrequent, circular stirring motions. It is very important to stir the water mixture very, very slowly and to persevere until all the lumps are gone and both mixtures have the appearance of an homogenous mixture.

8. Repeat steps 2-5 for the two mixtures. Did they behave as you would have predicted?

9. How are the two mixtures similar? In what ways do they differ?

10. Separately, pour each mixture in the palm of your hand and quickly "grab" it. What happens?

11. Pour another 2 tablespoons of water into a 6th cup and add 2 tablespoons of the corn oil/corn starch paste from step #6. Mix slowly as in step #7 and then repeat steps 2-5 and step #10 as before.

12. How is the water/paste mixture like the water/cornstarch mixture? How does it differ from the water/cornstarch mixture?

13. Describe the appearance of the water/cornstarch mixture when you stir it rapidly and compare it with the appearance of the water/paste mixture when you stir it rapidly. How are they alike? How do they differ? Compare the appearance of each mixture when poured out onto a plastic plate as in step #4.

Table I

	lower stirrer slowly	Pull stirrer quickly out	stab forcefully	stir vigorously	grab
water					
dry cornstarch					
cooking oil or corn oil					
cornstarch and water					
cornstarch and corn oil or cooking oil					
paste and water					

1. How does the behavior of cornstarch and water differ from either of its parts?

____

____

2. How does the behavior of cornstarch/corn oil mixture differ from the behavior of the cornstarch and water mixture?

____

____

3. How does the behavior of cornstarch/corn oil paste and water mixture differ from the behavior of the cornstarch and water, and the cornstarch/corn oil mixture?

____

____

4. When you stop "grabbing" the cornstarch/water in step #10, what happens to it?

   ____

5. When you stop "grabbing" the corn oil/cornstarch paste mixed in water, what happens to it?

   ____

6. Why would the cornstarch and water or the paste and water mixture be considered a "smart material?"

   ____

   ____

7. What possible practical or industrial applications could there be for the cornstarch and water or cornstarch and oil mixtures?

   ____

   ____

8. What is the definition of a dilatant? _______________________________________

Procedure B: Ferrofluids

1. Tip the tube of ferrofluid on its side, and measure the width of the band of ferrofluid.

2. Hold the different metal pieces magnets directly under the band of ferrofluid and describe the ferrofluid response. Measure any change in width and height and describe any visual change in appearance of the fluid, such as number and or relative size of any spikes. Is the distribution of spikes even?

3. Record your observations in Table II. of the data page.

Table II

Type of object	width of ferrofluid band	height of ferrofluid band	number of spikes	appearance of spikes	other observations
no object					
copper					
steel or iron					
aluminum					
Lead					
plastic					
glass					
horseshoe magnet					
bar magnet					
circular magnet					
refrigerator (plastic) magnet					

Questions:

1. Which materials tested were magnetic? ______________________________

____

2. How could you tell which materials were magnetic and which were not?

____

____

3. How did the appearance of the ferrofluids differ among the different kinds of magnets?

____

____

4. How could you use the ferrofluids to measure magnetic field strength?

____

____

5. How could you use the ferrofluids to measure direction of or flaws in, magnetic fields for different magnets?

____

____

9. Why would the ferrofluids be considered a "smart material?"

____

____

10. What possible practical or industrial applications could there be for ferrofluids?

____

____