Non-Newtonian fluid

What is Non-Newtonian fluid?

A non-Newtonian fluid is a fluid whose viscosity is variable based on applied stress or force. The most common everyday example of a non-Newtonian fluid is cornstarch dissolved in water. Behavior of Newtonian fluids like water can be described exclusively by temperature and pressure. However, the physical behavior of non-Newtonian fluid depends on the forces acting on it from second to second.

Interesting properties of Non-Newtonian fluids

If you punch a bucket full of non-Newtonian fluid such as cornstarch, the stress introduced by the incoming force causes the atoms in the fluid to rearrange such that it behaves like a solid. Your hand will not go through. If you shove your hand into the fluid slowly, however, it will penetrate successfully. If you pull your hand out abruptly, it will again behave like a solid, and you can literally pull a bucket of the fluid out of its container in this way. Non-Newtonian fluids help us understand the wide variety of fluids that exist in the physical world.

A search for non-Newtonian fluid on the internet brings up some interesting results. When combined with a oscillating plate, non-Newtonian fluids demonstrate other unusual properties, like protruding "fingers" and holes that persist after creating them. An oscillating plate applies stress on a periodic basis, rapidly changing the viscosity of the fluid and putting it in an odd middle ground between a liquid and a solid. At the same time, there are examples wherein one can place a bowl of cornstarch near a vibrating speaker to see the interesting patterns that are created on the surface of the mixture.

Physics of Non-Newtonian fluids[§]

To define it scientifically, a non-Newtonian fluid is a fluid whose flow properties are not described by a single constant value of viscosity. Many polymer solutions and molten polymers are non-Newtonian fluids, as are many commonly found substances such as ketchup, starch suspensions, paint, and shampoo. In a Newtonian fluid, the relation between the shear stress and the strain rate is linear, the constant of proportionality being the coefficient of viscosity. In a non-Newtonian fluid, the relation between the shear stress and the strain rate is nonlinear, and can even be time-dependent. Therefore a constant coefficient of viscosity cannot be defined.

§ Adapted in parts from an open Wikipedia source with no restrictions for education purpose - http://en.wikipedia.org/wiki/Non-Newtonian_fluid

Goal of experiment

Prepare a Non-Newtonian fluid – cornstarch and understand its properties.

Items needed for the experiment

Water, 3 to 4 small bags of corn starch, a medium sized bowl

Instructions for the demonstration

1. Start with the water in a bowl and start adding the corn starch to it. Roughly 5 parts cornstarch to 2 parts of water. You can use a spoon at first, but pretty quickly you'll be moving on to using your hand to stir it up.

2. Play with it to find out interesting properties.

    a. Gently push your hand into the starch. You would realize that your hand passes through easily.

    b. Now try to punch it with your hand while being careful that the mixed cornstarch doesn't splash out. You will feel the resistance offered by the starch as you do that since application of force (stress) changes the properties of this fluid to make it behave more like solid as explained earlier.

    c. If you have a small light rubber ball, you can actually see that ball bounce off the cornstarch if you drop it from some height over the fluid. If you drop it from point closer to the surface, the ball will rest on the fluid and slowly sink in.

Conclusions

This experiment demonstrates an interesting property of fluids that we see in everyday life. These properties are useful for certain applications. For example, this property helps when one wants the paint to flow readily off the brush when it is being applied to the surface being painted, but not to drip excessively. Another relevant fluid property in this class is evident by a ketchup which will not come out of the bottle until you stress it by shaking. This helps to control the flow of the ketchup.
A practical application for non-Newtonian fluids may be in body armor of the future. Since such fluids are usually flexible, they would allow soldiers to move freely when not under attack. But if confronted with a speeding bullet, they would quickly harder, performing like traditional armor. More research is of course necessary to see if non-Newtonian fluids are suitable for similar applications, but until then, it's sure fun to play with.

This is an activity that supports state physical science standards, engages students, and opens the imagination to future applications. This activity is appropriate for all elementary levels with the follow-up varying at the teacher's discretion for her scholastic level.

NYS Standard 4: The Physical Setting

Key Idea 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

P.I. - 3.1 Observe and describe properties of materials, using appropriate tools.

- 3.1b
- 3.1c
- 3.1e
- 3.1g

P.I. – 3.2 Describe chemical and physical changes, including changes in states of matter.

- 3.2a
- 3.2b
- 3.2c

NYS Standard 1: Analysis, Inquiry, and Design / Scientific Inquiry

Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

- S1.1
- S1.2
- S1.3

NYS Standard 6: Interconnectedness: Common Themes

Key Idea 2: Models are simplified representations of objects, structures or systems, used in analysis, explanation, or design.

Key Idea 4: Equilibrium is a state of stability due either to a lack of changes or a balance between opposing forces.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions.