Colloids and Emulsions

STEM Science and Engineering Saturday Seminar.
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Colloids and Emulsions.
These materials are very common and are amenable to some nice demonstrations, yet are not part of the usual curriculum. Topics include surface tension (and why droplets are spherical; why shaving cream acts like a solid even though it's made of liquid and gas); Brownian motion and the microscopic origin of heat; the behavior of many particles (phase transitions, how colloidal particles can spontaneously order themselves – an accurate demonstration of how water molecules form ice crystals); what is inside everyday materials.

I. What is inside some common, everyday materials.

Many materials around us are not easily identified as one of the three types of matter: solid, liquid or gas. (Which one of these is shaving cream?) Most materials you find in a classroom are mixtures (paint, milk, blood, cosmetics…) What is in these materials?

-What are colloids and emulsions?
(why don't the particles fall to the bottom of the container?? – see part III)

-A little magic trick: add salt to suspension of silica nanoparticles. (works OK with NaCl or table salt. ("Ludox AS-40" or AS-30). The sample was initially clear but that doesn't mean that nothing was there! The arrangement of the particles determines the optical and mechanical properties.

-Add lemon juice to skim milk. After mixing, swirly gently, don't shake or the clumps are broken and suspended). (I've heard that vinegar works too.) In this case, the sample was opaque at the start so there was clearly something in suspension (droplets and protein aggregates), but we still changed its appearance and properties (and taste).

-Look at cream, lotion or foam by eye: don't see any structural features, but they are there and they set the appearance and the feel/texture of the material.

II. Surface tension: Bubbles, droplets, and some geometry.

Materials that contain two immiscible liquids are common (vinaigrette, skin cream, mayonnaise, cream…)

-A bug walks into a bar… (Scene 10 of Pixar's A Bug's Life)

-What is the shape of a (small) bubble and why?

-The behavior is governed by a simple concept: the energy is proportional to the area of contact between the two fluids; the system tries to minimize area.

-Floating particles:
-which particles stick to which? What's the rule that describes this?
-floating or sinking particles; circular or non-circular.
'Build-your-own' structure with what is sometimes called the "Cheerios effect." Analogous to the crystallization of atoms, which are pulled together by attractions.

-Microscope image of a sphere sitting at water/air surface. The deformed shape is a logarithmic function (one of many physical examples of that esoteric mathematical function).

-Biology:

-See article/movie by David Hu and John Bush of MIT Math Department.
-The challenge of being an aphid: not drowning in pee.

-Technology:
Soap, solder, coatings such as paint,
-An interesting phenomenon understood purely by geometry: the Rayleigh instability.
(Mathematically accessible)
-Example: ask students to do a calculation with 1 cm^3 of water: is the surface area less for a long cylinder of radius 1 mm, or for a bunch of spheres of radius 3 mm? Ans: 2,000 mm^2 for the cylinder, 1,000 mm^2 for the spheres, so the latter has lower energy.

III. Energy and motion: (thermal motion/heat)
Atoms, molecules and small particles are never at rest (is this a misconception of students?):
-Light scattering from diluted ½ & ½ (glass slide and coverslip sealed with silicone). You see a "speckle pattern" caused by interference of lightwaves – think of many small stones thrown in to a pond, leading to a very complex, random-looking wave pattern. Look carefully at the spots.
- Compare the half-and-half to scattering from Teflon tape
(green laser pointer -- $10 from Amazon.com. Teflon tape is found in the plumbing supply section of a hardware store).
-Movie made with optical microscope shows the motion of little fat droplets.
-What would happen if we heated the sample?

IV. The structure of molecular solids
-Movie of Brownian motion, watch a crystal forming. These are not atoms, but the behavior is very similar.
-Movie by Bragg, Lomer and Nye showing a macroscopic model of metals.
-show microscopy images (static structure)?
-sizes of atoms (e.g. water) *vs.* sizes of these features.
-sizes of bacteria, λ, transistors, …

V. Feedback between technology and science
-Latex paint is hi-tech.
-structure and light scattering → paint, Tang®, lotions,…
-understanding rheology → latex paint (must have low viscosity when being applied with brush, but then must become very viscous so it does not flow off the wall.) Clothing dyes for patterns: they cannot flow too easily

Curriculum points that may be related to this workshop: (from Mass DOE)
PreK-2: solids, liquids and gases. (Defined by having a definite shape or not)
Grades3-5: basic properties of solids, liquids and gas.
Forms of energy, including heat (here manifested by the constant 'thermal motion')
Light travels in straight line, can be reflected and refracted.
Grades 6-8 :density vs. mass.
Mixtures vs. pure substances.

Chalk dust?
AAA batteries
Salt solution

Dish Soap
Cream
Skim milk
Digital camera
Little floating things
Laser pointer, mounts from the lab.

Schedule:

8:30 – coffee
9:00 start
Include two 15-minute breaks
Finish by 1 (before lunch)