August 2004

“Vision statement” from Howard A. Stone, Division of Engineering and Applied Sciences, Harvard University

Prepared for "Frontiers in Correlated Matter" (though I was unable to attend)

When thinking about science and engineering themes that commonly arise for the characterization of new materials and materials processing, for the description of biological phenomena and structures, and for the enhancement and optimization of biomedical processes, to name just a few, the subject of “complex fluids” and transport phenomena has a central role. Not surprisingly, many similar questions arise from the standpoint of industry (processing) and this link should not be missed since it often gives rise to new fundamental research questions and, at least in some sense, provides service to society.

To address many of these outstanding research questions (some which have been around for a long time), as well as to prepare for many similar questions that will continue to arise in the future, it is necessary to recognize that a complete understanding requires familiarity and understanding of solid mechanics, fluid mechanics, electrodynamics, statistical physics, and rheology, and indeed the complete toolkit of classical physics. In my own recent work we have addressed questions of multiphase flow in microfluidic devices, evolution of crystalline surfaces, swimming microorganisms, transport problems involving foams, fluid dynamics in thin films and contact line problems, etc. Progress in these areas requires close collaboration of experimental, theoretical, and numerical researchers, and increasingly requires researchers to be comfortable with the basic tenets and perspectives of the biological, chemical, engineering and physical sciences. Indeed, intuition is often crucial to making contributions to these multifaceted problems.

By their very nature, complex fluids have a macroscopic response that is much more complicated than simply being a collection of microscopic objects. The materials often have memory (their current flow features reflect their history), they can display fluid and solid-like properties, and there is no single universal description for characterizing the wide variety of materials under all possible flow or deformation conditions. Nevertheless, there are underlying principles from classical and statistical physics that provide a framework. Hence, it is intriguing to ask about the connections of studies of granular dynamics to studies of highly concentrated suspensions (or even glasses), and to consider the relation of friction in many different variants that often involve thin intervening films with simple or complex microstructures (the field of tribology remains part science and part art) to name just two examples.

The traditional boundaries of the science and engineering disciplines may still provide a reasonable framework for undergraduate education, but I do not think they necessarily provide a good perspective or framework for the research problems of significance today that arise in many areas of science and engineering. The area of complex fluids provides a training ground, and some may say a playground, for learning how to analyze problems where many different physical effects contribute. It is also a humbling experience but provides great satisfaction when it sheds light on either natural phenomena, assists a colleague in understanding new observations, or contributes toward the science and engineering activities that benefit society.