RAE Questions
Department of Chemical and Biomolecular Engineering, Spring 2006

Question 1. Since the discovery of carbon nanotubes many advances have been made in the synthesis and purification of Single Walled Nanotubes (SWNT), bringing the concept of a "space elevator", a cable up to 100,000 km long, tethered to the Earth and made of nanotubes, closer to reality. Separation of SWNT aggregates according to size, metallic/semiconducting properties and chirality has been attempted using a range of organic molecules ranging from small molecular weight species to biologically active DNA. Discuss SWNT synthesis methods. What properties are important? How could the best nanotubes for "space elevators" be produced? Discuss separation methods using organics and biomolecules such as DNA. What would be the main process concerns associated with SWNT separation for this futuristic application? Propose a synthesis and separation process for SWNT that would overcome some of the challenges associated with manufacturing a space elevator out of nanotubes.

Question 2. Contaminated soil and groundwater is often remediated through use of microbes. One of the limiting factors in bioremediation is transport of the bacteria to the location of the contaminants. Many bacteria that can degrade soil are both motile and chemotactic; they can sense concentration gradients and move preferentially in the direction of higher concentrations of degradable contaminants. In the absence of any concentration gradients, their mobility is similar to Brownian motion of suspended particles. Because of the transport considerations, it is important to understand the behavior of bacteria in porous media. Propose a research plan that incorporates both experiments and modeling, which could lead to a quantitative description of the transport behavior of bacteria in groundwater, in the presence of degradable contaminants. Some questions to address in your proposal: How do bacteria propel themselves? How can the effective diffusivity of bacteria be measured, both in free solution, and in porous media? How can the overall change in bacteria concentration with respect to time at any given point be described with a model incorporating effective diffusivity and chemotaxis? How could your model be used to improve a bioremediation process?

Question 3. Chemical vapor deposition is a commonly used process for creating very thin films of materials on flat substrates or those with topography. In this process, precursor chemical species are introduced to a reaction chamber containing the heated substrate; the heating decomposes the precursor species and drives the surface reactions resulting in the film. Recently, the concept of combinatorial CVD has been explored by several research groups; in this process, the gas phase composition is controlled to produce a spatial gradient in composition, resulting in a corresponding gradient in the film composition or other film property across the substrate.

It may be possible to extend combinatorial materials discovery principles to non-vapor phase systems. ZnO nanowires grown in a liquid solution phase show growth face morphology transitions as a function of solution composition – for this RAE problem, propose liquid phase reactor system that can control spatial gradients in the liquid phase composition for combinatorial study of the nanowire morphology. How would one verify the liquid phase composition by direct measurements? What would be involved in modeling this system, using basic reaction engineering principles?