Statement of Research and Teaching Interests

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I am seeking an academic position to establish original research programs in emerging and challenging areas of science and technology, while maintaining close collaboration with other researchers at the institute and at other institutions. In addition, I strongly believe that research and teaching activities are fundamental components for a successful academic career, and I am committed to enthusiastically pursue research and teaching excellence.

Research

I am engaged in several research projects in Fluid Mechanics and Transport Processes, all of which involve theoretical, computational and experimental studies.

In the most recent project, I am investigating the transport of suspended colloidal particles through a fluid filled nanochannel, where we found a novel adsorption phenomena that is controlled by the hydrophobicity of the channel wall[1]. This problem is of great importance in the rapidly evolving field of nanofluidics and we plan to extend our investigations to model protein translocation in bio-engineered nanopores. In a related project, I am investigating the chaotic dynamics, microscopic structure and rheological properties of non-Brownian suspensions in shear flows[6,7], which is a fundamental problem in hydrodynamics, but is also important to a variety of natural as well as engineering problems, from the dispersion and migration of red blood cells to the food industry. I am also investigating the transport properties of rock fractures, such as permeability and geometric dispersion, which play an essential role in applications such as subsurface hydrology, hydrocarbon recovery and waste storage[2–5].

In order to investigate these problems, I have used various powerful and complementary numerical methods that cover a wide spectrum of length scales, extending from Molecular Dynamics and Monte-Carlo simulations, that model the behavior at molecular scales, to Lattice-Boltzmann and Cellular-Automata methods, to describe the fluid behavior at intermediate, mesoscopic scales, and to Stokesian Dynamics simulations, which accounts for the macroscopic hydrodynamic interactions between suspended solids. I would like to emphasize, however, that my background as a graduate student is experimental, and in a core area of chemical engineering, that is, for my Ph.D. thesis, I investigated the convection, adsorption and dispersion processes present in the transport of an aqueous solution through a packed bed of activated carbon[8–13].

In terms of future work, I would like to pursue a number of research projects in the promising area of transport in micro- and nano-fluidic devices. This rapidly growing area of microfluidics can benefit enormously from numerical simulations and analytical studies, in problems ranging from the basic investigation of the fundamental physical chemistry at the molecular scales to the testing, improvement and exploration of new fluidic devices. Potential impact areas of microscale fluidic devices include high-throughput genomic and proteomic research[14], miniaturized total analysis systems[15,16], real-time portable detection devices, and microscale reaction and separation[17], among many others[18]. In this direction, I have started my own research on the development of efficient mixers at the micron scales,

[1] URL: `http://lisgi1.engr.ccny.cuny.edu/~drazer/drazer.html`

where inertia effects are negligible and therefore turbulent and chaotic flows are not available at practical operating conditions. I have recently presented a model of micromixer, conceptually analogous to the standard Kenics® device, but showing a very weak dependence of the mixing length on the Peclet number, a desired property in microdevices[19]. In addition, the transport of solid particles suspended in fluids is relevant to the majority of applications of microdevices, and I plan to investigate the behavior of colloidal particles in micro/nano confinement, by means of numerical simulations that include multi-scale methods, which would provide a bridge between the microscopic resolution of molecular dynamics techniques and mesoscopic approaches such as Brownian dynamics. Finally, some fundamental advantages of microfluidic devices lie not only in miniaturization itself but in exploiting novel or unusual physical aspects of fluid flow and mass transport available only at the microscale. In this context, I am interested in the development of sorting devices, for continuous molecular separation of chemical and biological species, that take advantage of the size-dependent diffusion of the suspended particles. In this case, there are several aspects requiring attention, such as the role of geometry in static devices and the possible presence of stochastic resonance induced by the thermal motion of the suspended particles. The possibility of shear-induced migration as a useful mechanism for separation also deserves some consideration.

It is clear that the research should certainly include an experimental component, which I am prepared to establish by both benefiting from, as well as contributing to the experience and expertise available at the various research laboratories in your department.

Research Background and Accomplishments

Micro/nano fluidics: Continuum theories commonly used to model the flow behavior of liquids and suspensions fail when the dimensions of the system approach molecular scales. We have therefore initiated a research effort to study the motion of nanoparticles in nanochannels via molecular dynamics simulations[1].

Suspensions undergoing shear: We study the dynamics of suspended spheres undergoing simple shear flow in the limit of zero Reynolds number (no inertia effects) and infinite Peclet number (no Brownian motion), using Stokesian dynamics, a numerical method that accounts for the hydrodynamic interactions between suspended spheres. The simulations provided clear evidence of the chaotic dynamics responsible for the loss of memory in the evolution of the system, ultimately leading to the phenomenon of shear-induced diffusion[6,7]. We also developed a molecular dynamics code to simulate the dynamics of sheared suspensions with finite Peclet and Reynolds numbers.

Transport in fractures: We investigate transport phenomena in geological fractures, with emphasis on the effects of the complex geometry of the pore space on the transport properties of the system. Our approach involves numerical simulations of the flow and transport of passive tracers through a single fracture, using Lattice-Boltzmann and Monte Carlo methods. I have implemented a parallel version of the Lattice-Boltzmann method that allows us to systematically investigate the transport properties of realistic fractures, which provided considerable insight into some recent experimental observations[4,5].

Transport and tracer dispersion in porous media: In my Ph.D. research, I investigated the transport of aqueous solutions through activated carbon porous media. I developed an experimental technique, based on mass transfer-rate measurements, that allowed us to identify the chemical (reversible adsorption) and geometrical (tortuous paths) effects on the overall effective diffusivity of solute particles inside the carbon grains[10]. We then developed an experimental method, based on tracer dispersion measurements, that permits to determine accurately the transport parameters describing the convection, dispersion and adsorption processes[8,9,11]. I also investigated the relation between the adsorption isotherm and the concentration decay observed in desorption experiments at long times[12,13].

Instabilities in miscible displacements: In an additional project during my Ph.D. I addressed the stable-unstable crossover in miscible displacements of non-Newtonian fluids in a radial Hele-Shaw cell. In these experiments we studied the fingering instability that occurs when a non-Newtonian, shear thinning aqueous polymeric solution, is displaced by a less viscous Newtonian fluid[20].

Teaching

I have always enjoyed teaching, whether as a teacher in secondary school when I was an undergraduate student or as a teaching assistance at the undergraduate and graduate levels while studying for my Ph.D. Not only am I passionate about teaching and advising student research, but I also consider it as an essential ingredient for a successful academic career.

As a faculty instructor I shall pursue teaching excellence, emphasizing a close and dynamic interaction with students, and implementing and constantly evaluating new didactic methods to facilitate the learning experience. I also believe in teaching students to think critically, challenging them, and expecting them to meet high standards.

Initially, I am prepared to teach courses in Fluid Mechanics, Transport Phenomena, Thermodynamics, Computational and Mathematical methods, and Statistical Mechanics, but I am also committed to expanding the spectrum of graduate and undergraduate courses I would teach. I also look forward to developing advanced graduate courses in my research specialty.

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