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Professor Rob de Ruyter van Steveninck
Professor and Chair, Faculty Search Committee
Biocomplexity Institute, Indiana University
Swain Hall West 117
Bloomington IN, 47405-7105

Dear Professor Rob de Ruyter van Steveninck:

I am writing to apply for a tenure track faculty position in the Department of Physics at Indiana University. Enclosed please find my resume for your review. I have also enclosed a list of references and statements of research and teaching interests.

My enclosed Curriculum Vitae provides further details of my education, research and teaching experiences. I would be very grateful for an opportunity to talk with you and to learn more about Indiana University.

I have broad interests and experience in research and also in teaching various disciplines within the physics, engineering and biomedical fields. My specific areas of expertise are mechanics of fluids and cardiovascular phenomena. I completed my Ph.D. in cardiovascular fluid dynamics at California Institute of Technology (Caltech) under the direction of Prof. Mory Gharib.

Before joining Caltech I earned my B.Sc. in Chemical Engineering at Isfahan University of Technology. I had a strong affinity towards natural sciences from an early age and I was able to enter the university program at the age of thirteen. After receiving my degree I was employed as a lecturer at the same school for nearly eight years, and I lectured for various courses in the Chemical Engineering Department. In addition, I was involved in organizing and directing the work in a number of laboratories. Based on these experiences, I decided that becoming a dedicated scholar and teacher was my career goal.

After joining the Chemical Engineering Department at Caltech, I began doing research on different areas of transport phenomena and fluid dynamics with particular attention to biofluid dynamics. Because of this interest, I worked in the Cardiovascular Fluid Dynamics Research Laboratory during my Ph.D. studies and designed various models for *in-vitro* studies of cardiovascular flows, from the embryonic stages to the fully-developed adult cardiovascular system. This has enabled me to do pioneering research on aortic flows and the interaction of fluid flow with biochemical responses in blood vessels. During this period, I had the opportunity to work with the medical schools of UCLA, Stanford University and Oregon Health Sciences University as well as having consulting opportunities with various mechanical heart valve companies. During the same period, I also taught at Occidental College as an adjunct professor in the physics department. The joy of teaching fundamental science courses has greatly reinforced my interest in academia.

I am applying for this position at Indiana University because it has an excellent reputation with a promising future, and I think that it would be an ideal environment in which to pursue and broaden my own career interests, especially given my interest in fundamental physical principles applied to interdisciplinary problems which I find very interesting. I am looking for a position with an institution where I can apply my skills and willingness to work eagerly with other people from diverse academic backgrounds and environments. I can offer you both effectiveness and longevity. I think my education, teaching experience, and enthusiasm for exploring new frontiers in the field of scientific education and working with undergraduate and graduate students would allow me to make a strong contribution to Indiana University and I thank you in advance for considering my application.

If any additional information is requested, please do not hesitate to contact me and I look forward to hearing from you.

Sincerely yours,

mehrdad m. zarandi

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Statement of Research Interests and Goals

My specific area of expertise is mechanics of fluids and biofluid dynamics. I completed my Ph.D. and postdoctoral work in this area at Caltech under the direction of Prof. Mory Gharib. Looking ahead, I am particularly interested in developing *in-vitro* model studies of the cardiovascular system and using non-intrusive flow visualization techniques for blood flow studies. I am also interested in developing analytical realistic models for such systems in order to understand the nature of the phenomena involved in the functioning of the cardiovascular system, which is crucial both for the design of artificial parts as well as for predicting the role of different parameters in the proper functioning of the cardiovascular system. This study not only would include the developed stages of the cardiovascular system but also would extend to the study of early stages of embryonic development. The reason for this is that many congenital heart diseases and problems which manifest themselves in the adult cardiovascular system have their roots in the embryonic stages. The similarity of the early stages of cardiovascular development in human beings and in many animals (for example in zebra fish or in chicken embryos) allows us to use the results of studies on fish or chicken embryos in order to understand many phenomena in the human cardiovascular system. For this purpose, I would like to develop a strong cardiovascular and biofluid research program that complements existing programs. I am also very interested in supervising and training undergraduate and graduate students, as well as in collaborating with other faculty members on research programs of common interest.

In my research I have a strong interest in analytical work. However, I like practical problems for motivation and guidance in performing analysis. My research to date has focused on determining the role of pulsatile flow and vortical structures in the flow in curved vessels, with particular interest in aortic flow. The nature of secondary flows in curved vessels and the differences between different flows — *e.g.* pulsatile versus steady or the role of vortex dynamics in such geometries — have been the focus of my studies. The important results of my studies of the level of shear stress in the human aorta of healthy adults have opened up a very interesting area of research in the interaction of flow and the endothelial linings of the blood vessels. My recent studies on embryonic flows have shown regions of high shear stress in the early stages of the development of the cardiovascular system. This reveals that the flow pattern in the early embryonic stage may have a role in the genetic regulation for the tissue development in later stages.

In general, there is a close relationship between many physiological problems of the cardiovascular system and the fluid dynamics of the system. A proper understanding of this relationship is crucial not only in predictive diagnosis and treatment of patients with those problems but also in the optimal design of artificial parts for the cardiovascular system — such as mechanical heart valves and bioprosthetic valves — as well as other applications such as cardiac assist devices. Therefore

I would like to devise elaborate *in-vitro* techniques which will allow us to measure quantitatively the physical properties which are important in the functioning of the cardiovascular system and which can supplement advanced clinical techniques — such as ultrasound and MRI — by providing a quantitative standard for judging these clinical imaging techniques.

My other contribution to the area of flow visualization is the development, in collaboration with Professor Gharib's research group, of a systematic approach for non-intrusive velocimetry and thermometry using microscale particles to track the flow (or the temperature) field. In addition to unifying the past results on the subject, this new general approach includes many situations that in the past defied a simple solution. We have already identified many interesting applications of our approach. We are planning to publish a monograph on this work which will serve as a supplement to the material found on the subject in various textbooks and which should be of benefit not only to graduate students doing research in the field of fluid dynamics but also to practicing engineers who are responsible for the design and performance evaluation of such systems. We believe that there are many other applications whose analysis can benefit from our approach. We would like in the future to use our approach for such applications to develop a unified analysis of their behavior in a form which can be easily evaluated numerically.

I would also like to pursue my research on the flow in elastic vessels and to study the interaction of the vortices with the flexible membranes and walls. These systems are currently receiving a great deal of attention from various biomedical scientists due to the extreme difficulty involved in analytical approaches to studying them and their inevitable occurrences in human organs.

Since all the demographic data indicate that the demand for such studies is expected to grow at a rapid pace, the future development of artificial organs and tissues has to focus on various issues specific to a fundamental understanding of naturally occurring phenomena in the human body, which with good reason seem to be the optimal choice or standard for design purposes.

My long-term research goal is to make a significant contribution in the development of these systems by working on the areas mentioned above. Given the ambience at Indiana University, it is my hope to build a strong program that involves various disciplines of science and engineering in research. I hope that I will be given the chance to interact with researchers, undergraduate and graduate students, to broaden my knowledge and experience, and to contribute to the research conducted in your department.

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Statement of Teaching Interests and Plans

I find teaching truly fascinating and I have enjoyed the interaction I have had, initially with high school students as a tutor during my undergraduate studies and later with undergraduate students at Isfahan University of Technology, Caltech and Occidental College. As a professor, I am eager to take an active role not only as an educator but also as an academic advisor and counselor for my students. My sensitivity to students with a wide range of backgrounds and career goals a together with my work in different academic settings gives me experience that can enhance my effectiveness and productivity. I would also like to take advantage of my interdisciplinary research to participate in the design of efficient scientific, engineering and interdisciplinary curricula, in the development of new coursesas well as in the adaptation of well-established classes. Because of my engineering background I would also be able to teach various courses on the technological and engineering side. More specifically, I am interested in teaching courses in a variety of subjects as described below.

1 Undergraduate Courses

I am interested in teaching undergraduate courses in the following subjects:

- **General Physics Courses**. The key to the comprehensive understanding of the phenomena of nature lies in the fundamental physical principles being formulated properly and clearly. Introductory physics courses should be given a prime importance to ensure a correct foundation for more complex phenomena. I enjoy teaching and developing courses in fundamental physics at any level. Such a course typically is an introductory, calculus-based (or an algebra-based course for life science majors) course covering fundamental concepts of physics including: momentum, energy, conservation laws, particle interactions, Newton's laws, oscillations, orbits and planetary motion and special relativity. A general physics laboratory taken in conjunction with this course will provide applications of the concepts of physics. The second part of this course will cover electric and magnetic fields, circuits, Maxwell's equations, electromagnetic waves, waves, interference and diffraction, wave-particle duality, atoms, nuclei and radioactivity, thermodynamics and statistical mechanics.
- **Classical Mechanics**. This is a one-year course in theoretical mechanics, and covers roughly basic definitions and principles of classical mechanics, conservation laws, systems of particles and motion of rigid bodies, oscillating phenomena and an introduction to generalized coordinates and the methods of Lagrange and Hamilton. Theory of mechanical vibration and

system dynamics are introduced in the second part of this course. At the level of *Theoretical Mechanics of Particles and Continua*, by Fetter and Walecka (with some mathematical simplifications and with emphasis on physical principles).

- **Statics and Dynamics**. This course is designed primarily for students who want to continue towards an engineering degree, it and applies the principles of classical mechanics to the analysis of force systems for rigid bodies, including equilibrium requirements, stresses in frames and trusses, forces in beams and cables, friction, centroids and moments of inertia. The second part of this course deals with the physical laws governing the motion of particles and rigid bodies, including studies of energy and momentum, kinematics, curvilinear motion and central forces. At the level of *Vector Mechanics for Engineers: Statics and Dynamics*, by Beer and Johnston.

- **Continuum Mechanics**. This course focuses on fundamental laws governing the mechanics of continuous media and different constitutive equations. Topics include: mechanics of solids, conservation equations, momentum transfer in fluids, and selected engineering applications. At the level of *Introduction to the Mechanics of Continua*, by Prager.

- **Equilibrium Thermodynamics**. Review of the first and second laws and their applications. Intermolecular forces and virial coefficients. Equations of state and thermodynamic properties of pure substances. Thermodynamics of gaseous and liquid mixtures. Theories of solutions. Phase and chemical equilibria. Energy conversion principles and applications.

- **Heat Transfer and Thermal Physics**. Focus on heat transfer with its relation to mass, and momentum transfer. Topics include: transport properties, conservation equations, conduction heat transfer in solids, convective heat, mass, and momentum transport in laminar and turbulent flows, phase change processes, thermal radiation, and selected engineering applications. At the level of *Introduction to Heat and Mass Transfer*, by Incropera and Dewitt. This course may be supplemented with parts of a textbook at the level of Kittel's *Thermal Physics*.

- **Methods and Techniques of Applied Mathematics**. A one-year course in applied mathematics pertinent to problems including:

  - Integral (Fourier, Laplace, Hankel) transforms and their application in signal analysis. At the level of *The Fourier Transform and its Applications* by Bracewell, and *Operational Mathematics* by R. V. Churchill.
  - Complex analysis. At the level of *Fundamentals of Complex Analysis for Mathematics, Science, and Engineering*, by E. B. Saff and A. D. Snider.
  - Differential equations, special functions and asymptotic expansions. At the level of *Advanced Mathematics Methods for Scientists and Engineers*, by Bender and Orzag.
  - An introduction to linear algebra and matrix theory. At the level of *Linear Algebra and its Applications*, by G. Strang.

2 Senior and Graduate level courses

I am interested in developing or adapting established senior and upper level courses in the following subjects:

- **Physical and Chemical Rate Processes.** The foundations of heat, mass, and momentum transfer for single and multiphase fluids will be developed. Governing differential equations; laminar flow of incompressible fluids at low and high Reynolds numbers; forced and free convective heat and mass transfer, diffusion, and dispersion. Emphasis will be placed on physical understanding, scaling, and formulation and solution of boundary-value problems.

- **Mathematical Biofluid Dynamics.** To introduce and explore in detail the concepts of mathematical formulation of external and internal flows in the human body. At the level of *Mathematical Biofluid Dynamics*, by James Lighthill.

- **Special Topics in Transport Phenomena.** Advanced problems in heat, mass, and momentum transfer. Introduction to mechanics of complex fluids; physicochemical hydrodynamics; microstructured fluids; selected topics in hydrodynamic stability theory; transport phenomena in materials processing; turbulence.

- **Thermodynamics of Irreversible Processes.** To cover topics in various areas of irreversible thermodynamics which occur frequently in biological phenomena. At the level of *Non-equilibrium Thermodynamics* by S. De Groot and Mazur and of *Thermodynamics of Irreversible Processes* by I. Prigogine. This course will cover the physics of the interfacial and membrane phenomena with a particular view to diverse biological phenomena — such as respiratory systems, kidney function and transport through biological membranes and interfaces.

- **Biofluid Dynamics.** To introduce the concepts of flow of biological fluids in the human body, the basics of fluid dynamics in large blood vessels, flow in elastic tubes, and the techniques of measurements in such systems. Introducing the role of fluid flow in activating biological processes and also signals and responses activated by fluid flow. At the level of *Fluid Dynamics of Large Blood Vessels* by T. J. Pedeley.

- **Fluid Dynamics of Nature.** To present the fundamental role of fluid dynamics in the shape and physiology of living beings from birds to fish and in their organ development.

- **Transport Processes in Biological Systems.** To present the transport laws in biological systems and the interaction of transport processes with the macroscale flow fields, tissue structure and membranes. At the level of *Transport Phenomena* by Bird, Stewart and Lightfoot with more emphasis on biomedical applications.