My work with graduate students

I am interested in supervising new graduate students with strong background in Applied Mathematics, Physics or Engineering. Some of the possible topics for a Master's or a PhD research project are described in my Research Experience.

I enjoy collaboration with my graduate students and make every effort that this collaboration is productive. Hence, most of my research publications in the leading Physics journals are coauthored with my graduate students. To illustrate how this collaboration works, I describe below how I published two very strong papers on graphene with one of my Master students in 2013.

The first paper, entitled "Effects of the structure of charged impurities and dielectric environment on conductivity of graphene", is authored by my student as the principal author and me as a co-author. It was published in the journal *Physical Review B* (PRB), Vol. 88 (2013), article number 205412. The paper deals with graphene, quite possibly the most prominent theme in Physics in recent years, which was discovered in 2004 in an experiment for which a Nobel Prize for Physics was awarded in 2010. The unprecedented explosion of research publications on graphene that ensued ever since its discovery was highlighted in 2014 when the European Commission for Science has chosen the Graphene Flagship to be one of the first recipients of a ten-year, €1 billion (CAD 1.456 billion) Future Emerging Technology research grant. The popularity and appeal of graphene in Nanotechnology is also witnessed on a daily basis by the University of Waterloo community members as they walk by the prominent hexagonal pattern that adorns the Quantum-Nano building on its campus.

The paper in question studies the electrical conductivity of graphene as its most critical property for applications. Being an all-surface material renders graphene extremely sensitive to its surrounding, which is both a blessing and a curse from a technological point of view. Both the experimentalists who try to exploit graphene properties by integrating it into elaborate nano-engineered structures and the theorists who try to understand and predict those properties via idealized models or complex *ab initio* computer simulations can benefit from a mathematical model that provides a comprehensive and flexible account of graphene's electrostatic interaction with the materials and probes in a realistically described surrounding.

The paper co-authored with my student attempts to provide such a model based on the Green's function method for the Poisson equation for graphene surrounded by layers with different material properties containing arbitrary distributions of charged impurities that are ubiquitous in the technologically relevant materials. In addition, we have developed a statistical description of the distribution of charged impurities based on the method of correlation functions. Besides analyzing the performance of our model in a very broad parameter space, we were able to calculate a set of results for graphene conductivity that was favorably compared in the paper with experimental data reported by a prominent group from Columbia University.

I believe that this paper is a fine example of the modeling approach that is typical for Applied Mathematics, where the two powerful techniques of Green's functions for partial differential equations and the correlation functions for statistical ensembles of particles were implemented to obtain tangible results in a problem of direct relevance to Physics and Engineering. Moreover, unlike the papers that use extensive computer simulations, our mathematical model is characterized by analytical transparency and computational portability, making it straightforward to adopt and implement by any experimental or theoretical group.

We chose to publish our paper in PRB because that journal attracts the largest readership in the area of graphene (searching the Web of Knowledge for the number of papers containing the key words *graphene* and *conductivity* showed that PRB by far exceeds all other journals). According to the Thomson Reuters Journal Citation Reports (http://admin-apps.webofknowledge.com/JCR/JCR), the Impact Factor of PRB is 3.767, its Eigenfactor Score is 0.73336, and its Article Influence Score is 1.429, all testifying to the prestige and high impact of articles published in this journal. (Note that the Eigenfactor and Influence Scores correct for the difference in citation patterns seen in different subject areas, allowing for a more direct comparison between clusters of journals with a more specific focus.)

Our paper was reviewed in PRB by three anonymous referees who are perceived to be top experts in the area of graphene. The first reviewer realized that we treat graphene in "a realistic dielectric environment" and concluded that "This is a really impressive paper that I recommend for publication essentially in its present form." The second reviewer noted that "The subject discussed in this paper seems to be important to the field of the graphene-based electronics research" and he/she only requested one minor comment to be made. The third reviewer stated that "This manuscript advances our knowledge of the effects of the substrate (dielectric properties, geometry and charged impurities) on electronic transport in graphene" and only recommended to reorganize the presentation of the multitude of our results. Needless to say, we have successfully addressed those few comments and submitted a revised manuscript that was quickly accepted by the PRB Editors.

Being carried by the momentum of research done for his first paper in PRB, my student soon proposed that we extend our statistical approach to calculate the auto-correlation function of the electrostatic potential in graphene due to randomly distributed charged impurities. To our surprise, we were able to reproduce an independent set of recent experimental data for the potential fluctuations in graphene, and hence we decided to submit that result to the journal *Applied Physics Letters* (APL), which is yet another influential AIP journal that reports short papers on graphene research (Impact Factor 3.794, Eigenfactor Score 0.58720 and Article Influence 1.355). To our even greater surprise, our short report was accepted in just two weeks by an Editor who stated "Thanks to have submitted your work. I am glad to communicate that content of the paper is very original and well structured. The paper does not need any additional modification or integration." This second paper, entitled "Potential fluctuations in graphene due to correlated charged impurities in substrate" is published in APL, Vol. 103 (2013), article number 171606.