Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Sarah Hamerling
High School: Hunter College High School, New York, NY
Mentor: Dr. Udayan Mohanty
Project Title: *On the 2- and 3-dimensional cylindrical nonlinear Poisson-Boltzmann equation* (Biophysics)

The electrostatic properties of DNA can elucidate phenomena such as DNA translocation through charged nanopores and stabilization of nucleic acid conformations. We derived an analytic solution to the nonlinear Poisson-Boltzmann equation for the potential and counterion density between coaxial charged cylinders analogous to the nanopore system, a geometry previously unsolved for in the literature. In three dimensions, the potential varies with the distance r from the axis as $\ln(r^2 \cos^2(\ln r))$ and in two dimensions as $\ln(\cos^2 r)$, with coefficients arising from a transcendental integration constant. We compared these results to those for lone cylinders and cylinders near a planar surface, finding an increase in the potential at the surface of the cylinder by factors of 4 and 2, respectively, in physiological conditions, indicating stabilization of more tightly wound nucleic acid helical structures. In two dimensions, we found a quadratic dependence of the free energy of the system on the electrostatic coupling parameter, or the ratio of Bjerrum to Gouy-Chapman lengths, in addition to shared linear and hidden transcendental dependencies in both dimensions. Also proposed are potential avenues by which mean-field Poisson-Boltzmann theory may be corrected to encompass correlation and fluctuation effects.