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A COORDINATE INVARIANT THEORY FOR SPACE CHARGE LIMITED EMISSION USING VARIATIONAL CALCULUS

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Classical theories of space-charge limited emission (SCLE) for coaxial cylindrical and concentric spherical diodes were first formulated by Langmuir and Blodgett (LB) [1,2]. Recent studies have improved upon the LB series expansion using analytical techniques [3,4]; however, they assume zero space-charge and cannot predict single-particle trajectories or solve for the shape of the potential function across the gap. This presentation applies variational calculus and the minimum energy principle to obtain fully analytic solutions for the potential and current-voltage behavior of these diodes. We obtained excellent agreement with previous simulations and experiments, with better agreement at more extreme ratios of anode to cathode radius compared to other theoretical approaches. The implications of these equations and the potential extension to multi-dimensional SCLE and other electron emission mechanisms will be discussed.

1. I. Langmuir and K. Blodgett, "Currents limited by space charge between coaxial cylinders,"Phys. Rev., vol. 22, 347-356, 1923.
2. I. Langmuir and K. Blodgett, "Currents limited by space charge between concentric spheres,"Phys. Rev., vol. 24, pp. 49-59, 1924.
3. X. Chen, J. Dickens, L. L. Hatfield, E.-H. Choi and M. Kristiansen, "Approximate analytical solutions for the space-charge-limited current in one-dimensional and two-dimensional cylindrical diodes,"Phys. Plasmas, vol. 11, pp. 3278-3283, 2004.
4. Y. B. Zhu, P. Zhang, A. Valfells, L. K. Ang, and Y. Y. Lau, "Novel scaling laws for the Langmuir-Blodgett solutions in cylindrical and spherical diodes,"Phys. Rev. Lett., vol. 110, 2013, art. no. 265007.

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