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PHYSICS-INFORMED NEURAL NETWORKS FOR STUDIES ON ELECTRON SWARMS IN GASES

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Abstract. Physics-informed neural networks (PINNs) have attracted much attention as a novel method for solving forward and inverse problems of partial differential equations (PDEs) (Raissi et al. 2019). In the PINNs, an artificial neural network (ANN) is trained to represent a solution of PDEs. The partial derivatives of the function represented by ANN can be computed analytically without generating grids. This mesh-free feature is an advantage when we tackle high-dimensional problems, such as solving electron Boltzmann equation (BE). We have developed two applications of the PINNs for studying electron swarm physics in gases. The first is solving electron BE using PINNs to calculate electron velocity distribution functions (EVDFs). So far, EVDFs in hydrodynamic equilibrium at DC electric and magnetic fields (Kawaguchi et al. 2020, 2022) and periodic equilibrium EVDFs at RF electric fields can be calculated (Kawaguchi et al. 2023a). The second is measuring electron transport coefficients by combining electron swarm experiments and PINNs (Kawaguchi et al. 2023b). The governing equation describing spatial and temporal development of measured data is discovered using PINNs. The electron continuity equation can be found from measured electron swarm maps under DC electric fields, allowing us to measure transport coefficients in the continuity equation, such as effective ionization collision frequency, bulk drift velocity, longitudinal diffusion coefficient, third-order transport coefficient and so forth.

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