On the Boris solver in particle-in-cell simulation

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Particle-in-Cell (PIC) simulation has been extensively used in theoretical plasma physics. In PIC simulation, the Boris method is a de facto standard to advance charged particles. Owing to its accuracy, robustness, and stability, it has been used for nearly 50 years. Meanwhile, there is a growing demand for better particle solvers in PIC simulations in plasma astrophysics.

As a first topic, we will introduce a new form of the Boris integrator to advance particles. The new form takes advantage of two exact solutions for the Coulomb-force part and for the Lorentz-force part, and then it achieves the second-order accuracy. Numerical tests are conducted by test-particle simulations and by PIC simulations, in comparison with the Boris solver. The new solver provides a better accuracy than the Boris solver in most cases, whereas it only requires few extra computation time.

As a second topic, we will present a numerical boost problem in a relativistic magnetized flow. It is found that gyration-based solvers lead to an unphysical boost in the flow direction in the relativistic regime. Our analysis and numerical tests reveal that the numerical boost for cold particles is proportional to the square of the timestep, i.e. (delta t)∗∗2. Our new solver reduces the numerical boost to 1/3 of that of the Boris solver. This fact gives us further confidence to employ the new solver.