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On Charge Conservation in Particle-In-Cell Methods[1] ALEXANDER S GLASSER, HONG QIN, Princeton University — In recent years, much work has been devoted to exactly-charge-conserving particle-in-cell (PIC) methods that simulate the collective dynamics of particles and electromagnetic fields. While it is rightly observed that these methods' gauge symmetry gives rise to their charge conservation, this causal relationship has been loosely described in ad hoc derivations of the associated conservation laws. In the following work, we more firmly establish the causal relationship between PIC methods' gauge symmetry and charge conservation. In the formalism of Noether's Second Theorem, we demonstrate that gauge symmetry in Lagrangian variational PIC methods gives rise to local charge conservation as an off-shell identity. We further examine Hamiltonian PIC methods, and discover sufficient conditions for the preservation of the momentum map in splitting schemes. We elucidate the status of local charge conservation laws in such splitting methods, and explore the improved preservation of structure in the covariant (i.e. multisymplectic) Hamiltonian formalism.

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Alexander Glasser
Princeton Plasma Physics Laboratory

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