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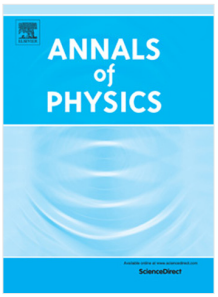

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ACCEPTED MANUSCRIPT

The origin of the energy-momentum conservation law

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Abstract

The interplay between the action–reaction principle and the energy-momentum conservation law is revealed by the examples of the Maxwell–Lorentz and Yang–Mills–Wong theories, and general relativity. These two statements are shown to be equivalent in the sense that both hold or fail together. Their mutual agreement is demonstrated most clearly in the self-interaction problem by taking account of the rearrangement of degrees of freedom appearing in the action of the Maxwell–Lorentz and Yang–Mills–Wong theories. The failure of energy-momentum conservation in general relativity is attributed to the fact that this theory allows solutions having nontrivial topologies. The total energy and momentum of a system with nontrivial topological content is found to be ambiguous, coordintization-dependent quantities. For example, the energy of a Schwarzschild black hole may take any positive value greater than, or equal to, the mass of the body whose collapse is responsible for arising this black hole. We draw the analogy to the paradoxial Banach–Tarski theorem; the measure becomes a poorly defined concept if initial three-dimensional bounded sets are rearranged in topologically nontrivial ways through the action of free non-Abelian isometry groups.

Keywords: action–reaction, translation invariance, energy and momentum conservation, rearrangement of initial degrees of freedom

1 Introduction

By summing the basic advances in physics of the 19th century, Max Planck placed strong emphasis on the action–reaction principle as the rationale of momentum conservation [1]. On the other hand, following Noether's first theorem [2], we recognize that any dynamical system exhibits momentum conservation if the action of this system is invariant under space translations, in other words, the momentum conservation law stems from homogeneity of space.

In nonrelativistic mechanics, Newton's third law is consistent with the requirement of translation invariance. Indeed, the forces exerted on particles in an isolated two-particle

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