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The first law of binary black hole mechanics

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First laws of black hole mechanics, or thermodynamics, come in a variety of different forms. We establish a first law of mechanics for binary systems of point masses moving along circular orbits. This relation is derived from first principles in General Relativity, and is explicitly shown to hold up to very high orders in the post-Newtonian approximation. Analogies are drawn with the single and binary black hole cases, revealing intriguing formal relations between point masses and black holes. Several applications to gravitational-wave source modeling are discussed, such as the computation of the binding energy E and total angular momentum J of the binary system, at leading order beyond the test-particle approximation. The resulting expression for the coordinate invariant relation E(J) is shown to agree remarkably well with the exact results from recent numerical simulations of comparable-mass non-spinning black hole binaries.