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Mass–energy connection without special relativity

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In 1905, Einstein gave his first derivation of the mass-energy equivalence by studying, in different reference frames, the energy balance of a body emitting electromagnetic radiation and assuming special relativity as a prerequisite. In this presentation, I reassess the logical soundness of Einstein's approach and the validity of one assumption crucial for the derivation (that has nothing to do with special relativity). If we accept that assumption as valid, the essence (but not the formula) of the mass-energy equivalence can be derived without the need for special relativity or any full-fledged physical theory. However, the assumption is unsupported from a physical viewpoint, and its use makes Einstein's 1905 derivation circular. I also show why the widely received interpretation of $E=mc^2$ (i.e., every kind of energy has a mass and vice versa) is problematic.

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