Review of: "Does energy always have mass?"

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The manuscript presents a critical stance towards the mass-energy equivalence principle, as proposed by Einstein. While the author has every right to critique this well-established principle, it appears the cases presented as counterarguments have their own shortcomings.

Historically, Einstein's insight has sometimes been misunderstood. When a body's internal energy increases by ΔE, both its effective inertial and gravitational masses also increase by $\Delta E/c^2$. The origin of this internal energy change is irrelevant; it could arise from radiation absorption or mechanical work. While some physicists avoid terms like "relativistic mass" and prefer to exclusively refer to "energy", the dynamical behaviour of a system still reflects its internal energy.

It's crucial to distinguish between "mass-energy equivalence" and concepts like "mass-energy conversion". Energy is not "converted" or "transformed" into mass; rather, energy is equivalent to mass. The term "rest mass" is distinct from the effective mass associated with an object's energy content.

A common misconception involves a body absorbing heat, increasing its internal energy. Some argue that if the body's energy starts as mc^2 and then adds heat Q, the final energy would be $mc^2 + U$ (with U being the increase in internal energy). If there is no external work done on the body, then the first law of thermodynamics dictates that $U = Q$. If the mass m also increases, it might appear that energy is created. However, this is a flawed interpretation, as it involves double-counting the energy. In microscopic view, the internal energy here is just the potential and kinetic energy of the constituent particles, which is included in the expression of the relativistic mass.

Similarly, in discussions about radioactive decay, some reference the "conversion of mass" to energy. This viewpoint oversimplifies the process. The energy was always present, initially as binding energy, and decay merely changes its manifestation. To consider both the binding energy and the change of mass would involve double-counting the energy, as elaborated above.

Regarding gravitational potential energy, the author seems convinced that prior works neglect it. However, when elevating a particle, one must consider the entire Earth-particle system, not just the particle in isolation. The dynamics of the Earth-particle system has changed because the system's mass would appear to have increased. However, it is wrong to say that the particle becomes more massive as the gravitational potential energy is not stored within the particle but within the gravitational field.

In the realm of general relativity, anything that curves spacetime is energy. Gravity is the curvature's observable effect.

The red-shifting of photons, as mentioned, results from spacetime bending, with the lost energy being “stored” in the field, analogous to energy stored in electromagnetic fields. The author mentioned that the red-shifting argument is problematic, however, I believe the proof he presented is flawed.

Regarding the capacitor, it indeed becomes more massive (albeit insignificantly so) when storing electrical energy due to the energy stored in its electric field.