Review of: "On the Mass of (Gravitational) Potential Energy"

Emil Roduner[1]

1 Universität Stuttgart

Potential competing interests: No potential competing interests to declare.

The question of whether (gravitational) potential energy has mass is basically interesting. The problem is that the manuscript is based on a fundamental and obviously widespread misunderstanding. It is correctly stated that Einstein's relation $E = mc^2$ prescribes an **equivalence** between energy and (rest) mass. But an equivalence is not an identity. Similarly, 10 Euros are equivalent to a number of Dollars; they are two forms of money, but they are not identical. A bank will do the conversion. The fundamental question is whether potential energy and mass are also convertible. No such mechanism is offered, and I am not aware of any such mechanism. An example where the mass to energy conversion works is the beta decay of the free neutron, which results in a proton, an electron, and an antineutrino. There is a mass defect in such reactions (see your references 12 and 13), meaning that the sum of the masses of the proton and electron is less than that of the initial neutron. The missing mass has been converted into the kinetic energy of the products. If a body is lifted to a height h in a gravitational field, as in Figure 1, then the masses of the two interacting bodies remain the same. The work mgh was not at the cost of a fraction of the mass of one of the bodies, but it was spent from some other source that is not mentioned. If the lifted body is dropped back, the potential energy mgh is converted into heat, but not into mass. Energy is conserved, and potential energy can be considered **equivalent** to an amount of mass with a known conversion factor, but they are not an identity. Mass remains mass, and potential energy remains potential energy.

Figure 3 provides an example that involves the annihilation of mass. This is also problematic. Particles can annihilate with their antiparticles, e.g., electrons with positrons to give two or, in some cases, three gamma rays. Also, the reverse process is known: two gammas of sufficient energy can undergo pair production, giving an electron and a positron. Not only energy but also linear and angular momentum and some other properties such as lepton number must be conserved in such processes. I am not aware of any process that converts a particle of a given mass to just a photon.

I would like to add a note of caution on the principle of energy conservation. We believe in an energy-time interval uncertainty relation. This means that for quantum systems, energy conservation can be violated for a certain period of time. The shorter the time period, the larger can be the violation. Free quantum systems can oscillate between their eigenstates, but the average energy is still conserved.

It is difficult to suggest improvements to this paper. A completely different concept would be needed.