**Historical burdens on physics**

### 113 Potential energy

**Subject:**
From an encyclopedia:

“The potential energy is one of the energy forms of physics. It is that energy which a body possesses due to its position in a force field (for instance a gravitational or an electric field).”

From a school book:

“Example: The potential energy of a satellite...”

**Deficiencies:**

In the citations the potential energy is attributed to a body.

If one is convinced that energy can be localized (and this is the general conviction of physics since the end of the 19th century), then one will understand the citations as follows: Bodies contain potential energy. And as a consequence: The potential energy must be distributed within the bodies in a well-defined manner. These conclusions, however, would not be correct. The potential energy is not contained in the bodies but in the fields that are mainly situated between the bodies.

In particular our second citation shows that something cannot be correct. If the potential energy is attributed to and thus localized within the satellite, then the potential energy of the system earth-moon would be localized within the moon, and when finally considering a binary star system composed of two stars of equal mass the potential energy would be localized in only one of the stars – which cannot be true for symmetry reasons. Sometimes the term potential energy is also used when the momentum transfer between two bodies goes not via a field but by means of an elastic spring. In this case usually the energy is correctly attributed to the spring. However, the name “potential” for the energy is not convenient. According to the Merriam-West dictionary, the adjective “potential” means: “existing in possibility; capable of development into actuality”. This definition does not agree with the energy that is stored in a spring. Just as the kinetic energy is contained within a moving body, the energy that is supplied to a spring when expanding it is stored within the spring. For both of them a density distribution can be indicated (i.e. the energy can be localized) and both can (in principle) be measured by the relativistic mass increase.

**Origin:**

The inconvenient wording seems to have several causes or origins.

1. The concept potential energy stems from a time when energy could not yet be localized (before 1890).

2. When teaching, the concept is usually introduced by considering a small body in the gravitational field of the earth. In this case the potential energy can be calculated by means of the equation \( E = m \cdot g \cdot h \). Here \( h \) is the height of the small body with respect to a zero point that is firmly connected with the earth. \( h \) does not appear as the distance between two bodies, namely the small body and the earth, and \( h \) does not appear as the height.
of the earth above the small body, but that of the small body above the earth or the surface of the earth.

3. Often, the context in which the term is employed is the movement of two bodies that interact gravitationally, and where the mass of one of the bodies is much larger than that of the other. Let us consider the famous falling apple and begin with the momentum balance (in the center of mass system): Only the earth and the apple participate in the process; the momentum that the apple is gaining is lost by the earth. The momentum of the field is almost zero and does almost not contribute to the momentum balance. Things are different when we consider energy. The kinetic energy of the earth does practically not change (since the mass of the earth is much greater than the mass of the apple). The energy which the apple is receiving does not come from the earth but from the gravitational field.

The same is true when two bodies are coupled by a spring instead of a field. Here too, the momentum exchange is between the two bodies, whereas the energy exchange is between the light body and the spring.

Disposal:

Small solution: Avoid formulations that attribute the potential energy to a body. Here is an example from another school book:

“The potential energy of the system ‘earth - body of mass $m$’ with respect to a reference level, that can be arbitrarily chosen, is…”

This wording is better than that of our initial citations. However, it still suggests the idea of actions at a distance, since the system is called “earth - body of mass $m$”. The field as a part of the total system is not mentioned.

Great solution: Introduce the field from the very beginning as the third partner and say clearly where the energy is localized, namely within the field.

The adjective potential should be avoided in any case.

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