8 Conservation laws

Subject:

It is possible to state whether any extensive quantity is conserved or not. Some extensive quantities obey (as far as we know) a universal conservation law: energy, momentum, angular momentum, electrical charge, lepton number, baryon number, color charge, etc. There is one quantity that obeys a “half conservation law”: Entropy can be produced, but not destroyed. Each quantity that is not generally conserved may be conserved under certain circumstances. As an example, entropy in reversible processes behaves like a conserved quantity. The amount of substance is not generally conserved, however there are many processes in which it behaves like a conserved quantity.

Deficiencies:

If the extensive quantities are placed in the foreground, then one gets a representation of physics in which the various sub-fields reveal the same structure. Mechanics, thermodynamics, electricity and chemistry appear as special cases of a uniform structure of concepts. In order to be able to take profit of this structural similarity, it is necessary that the various corresponding physical quantities are treated in an analog manner. Therefore it is recommendable that the conservation or non-conservation of the various extensive quantities is treated in analogous ways, on equal footing. However this is not usually done.

For instance, the conservation of energy is presented as one of the most important principles of the whole of physics. The conservation of momentum is dressed in Newton's laws, such a strangely complicated outfit that this simple statement can no longer be recognized. Completely different again is the electrical charge: Over its conservation not a single word is wasted, since it is usually presupposed as obvious. The simple fact that entropy can be produced but not destroyed is sometimes found in schoolbooks in the small print, and usually in the place where instruction never reaches. The non-conservation of the amount of substance is never formulated as a theorem, nor is the fact that for certain classes of processes the amount of substance is conserved. Instead of formulating and applying the simple and useful conservation laws that are known from nuclear and particle physics, precious teaching time is wasted with the discussion of details of special radiation meters.

Origin:

The statements about conservation or non-conservation of extensive quantities reflect the historical development of physics. If the discovery and formulation of such a statement was difficult and took a long time, or if the validity of the statement was questioned for a long time, then much time will also be reserved for teaching the concept, and the statement will be presented as particularly important. The clearest example of this is energy conservation. One might argue that the principle of energy conservation is so fascinating for us because it forbids something with which one could make a lot of money. This is true. However, it also shows the lack of imagination of the would-be perpetual motion inventors, since they could also make a lot of money by breaking any of the other conservation laws.

On the other hand, if the discovery of a conservation or a non-conservation theorem was quick and easy, and if the statement was historically not doubted, then the theorem is also treated quickly in the classroom, or not at all.

Disposal:

Instruction would win if one:

1) clearly formulated conservation or non-conservation for each extensive quantity;
2) clearly pointed out the importance of conservation or non-conservation (particularly in the case of electrical charge, amount of substance, lepton number and baryon number);
3) did not exaggerate the importance of conservation (as with the energy).

Friedrich Herrmann, Karlsruhe Institute of Technology