Topic Page: Conservation Laws

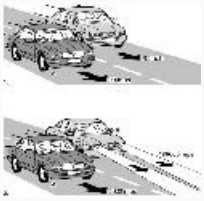

Image from: **relativity** in *The Macmillan Encyclopedia*

Summary Article: **conservation laws**
From *The Columbia Encyclopedia*

in physics, basic laws that together determine which processes can or cannot occur in nature; each law maintains that the total value of the quantity governed by that law, e.g., mass or energy, remains unchanged during physical processes. Conservation laws have the broadest possible application of all laws in physics and are thus considered by many scientists to be the most fundamental laws in nature.

Conservation of Classical Processes

Most conservation laws are exact, or absolute, i.e., they apply to all possible processes; a few conservation laws are only partial, holding for some types of processes but not for others. By the beginning of the 20th cent. physics had established conservation laws governing the following quantities: energy, mass (or matter), linear momentum, angular momentum, and electric charge. When the theory of relativity showed (1905) that mass was a form of energy, the two laws governing these quantities were combined into a single law conserving the total of mass and energy.

Conservation of Elementary Particle Properties

With the rapid development of the physics of elementary particles during the 1950s, new conservation laws were discovered that have meaning only on this subatomic level. Laws relating to the creation or annihilation of particles belonging to the baryon and lepton classes of particles have been put forward. According to these conservation laws, particles of a given group cannot be created or destroyed except in pairs, where one of the pair is an ordinary particle and the other is an antiparticle belonging to the same group. Recent work has raised the possibility that the proton, which is a type of baryon, may in fact be unstable and decay into lighter products; the postulated methods of decay would violate the conservation of baryon number. To date, however, no such decay has been observed, and it has been determined that the proton has a lifetime of at least 10^{31} years. Two partial conservation laws, governing the quantities known as strangeness and isotopic spin, have been discovered for elementary particles. Strangeness is conserved during the so-called strong interactions and the electromagnetic interactions, but not during the weak interactions associated with particle decay; isotopic spin is conserved only during the strong interactions.

Conservation of Natural Symmetries

One very important discovery has been the link between conservation laws and basic symmetries in nature. For example, empty space possesses the symmetries that it is the same at every location (homogeneity) and in every direction (isotropy); these symmetries in turn lead to the invariance principles that the laws of physics should be the same regardless of changes of position or of orientation in space. The first invariance principle implies the law of conservation of linear momentum, while the second implies conservation of angular momentum. The symmetry known as the homogeneity of time leads to the invariance principle that the laws of physics remain the same at all times, which in turn implies the law of conservation of energy. The symmetries and invariance principles underlying the other conservation laws are more complex, and some are not yet understood.

Three special conservation laws have been defined with respect to symmetries and invariance

principles associated with inversion or reversal of space, time, and charge. Space inversion yields a mirror-image world where the “handedness” of particles and processes is reversed; the conserved quantity corresponding to this symmetry is called space parity, or simply parity, *P.* Similarly, the symmetries leading to invariance with respect to time reversal and charge conjugation (changing particles into their antiparticles) result in conservation of time parity, *T*, and charge parity, *C.* Although these three conservation laws do not hold individually for all possible processes, the combination of all three is thought to be an absolute conservation law, known as the *CPT* theorem, according to which if a given process occurs, then a corresponding process must also be possible in which particles are replaced by their antiparticles, the handedness of each particle is reversed, and the process proceeds in the opposite direction in time. Thus, conservation laws provide one of the keys to our understanding of the universe and its material basis.

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