# Letters

## Time Dilatation

In a recent article [*Science* **137**, 18 (1962)], Sebastian von Hoerner of the Astronomisches Rechen-Institut considers the general limits of space travel. It is a fascinating discussion, but it appears to me that von Hoerner is making unwarranted assumptions when he attempts to apply Einstein's relativity theory to biological time. In his defense it may be noted that he carefully indicates that his estimate is based on relativistic formulas. On the basis of Einstein's theory, von Hoerner concludes that 60 years for a crew member aboard a rocket attempting an interstellar trip of 760,000 parsec will be equivalent to a life span of $5 \times 10^6$ years on earth.

Einstein's relativity theory states that $t^* = kt$ where $t^*$ is different from $t$ and the difference depends upon $k$, $k$ being dependent on velocity. This equation became a sensation through the popularized interpretation that the rate of a timekeeper depends upon the velocity of its motion. This has never been proved or disproved experimentally. Einstein's theory, being based upon these considerations, does not permit the conclusion that intermolecular biochemical reactions will achieve essentially steady-state kinetics when the system is moving at a high velocity. The time dilatation concept does not provide evidence to indicate that a twin on a rocket moving at a velocity nearly that of light would live $5 \times 10^6$ earthly years while his twin on earth lived 60 years. The mathematical equations of Lorentz and Einstein fit certain phenomena of light as related to time and to space. These equations also apparently fit the decay pattern of mesons. There is, however, no justification, in the absence of experimental verification, for assuming that these mathematical formulas also hold for the intermediary metabolism of the light process, which is primarily based not upon the velocity of light in an ether but upon intermolecular biochemical reactions transcribing what is known as an unsteady kinetic state in a semiclosed system. Indeed there is no known causal means by which greatly increased velocity could alter, without destroying the very biochemical basis of the life process, those metabolic changes which are responsible for the aging process.

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I would first of all strongly recommend avoiding the concept of "biological time" as possibly being different from "physical time" or "atomical time" or the like. Because the introduction of this concept would mean a more drastic break with classical physics than the one due to relativity.

We describe positions and movements of objects in a frame of three space coordinates and one time coordinate no matter whether we are regarding electrons, complex things, living beings, or stars. There are no different types of time, just *the* time as one of the coordinates of our frame of reference. We may of course measure the time by different means, like atomic clocks, watches, the speed of biological changes, or the rotation of the earth. But it is always *the* time we measure—just as there are no different types of distances.

In classical physics many properties such as time, space, and mass were considered *absolute* properties; the time interval between two events, the length of a rod, or the mass of an object were regarded as being exactly the same when measured by different observers under different conditions. The first slight break came within classical physics itself; it was found that an electrically charged moving body, for example, has no magnetic field at all as seen by a co-moving observer, while an observer at rest will measure a magnetic field connected with that body. It is found that even at moderate speed electric and magnetic fields are *relative* instead of being absolute.

Einstein's special theory of relativity now states that time intervals, lengths, and masses are relative properties rather than absolute ones. Even the concept of simultaneousness is abandoned for two events occurring at different places. But all of these relativities occur only if the velocity differences of different observers are comparable to the velocity of light, which lies far above all of our every-day experiences. Time, now, is relative, but still it is *the* time, one of the four coordinates of any frame of reference.

Consider a rocket with a velocity close to that of light, as seen from the earth. Within that rocket all processes will develop at their usual speed, if time is measured in a co-moving frame; no differences will show up between atomic clocks, watches, and biological changes. (Otherwise one could tell the velocity of the rocket just by measuring such differences within the rocket. This would enable one to define an absolute frame of rest, and this is impossible not only according to Einstein but according to Galileo, too.) But, as seen from the earth, the time scale of this co-moving frame of reference will be different from the scale of a frame resting on the earth. Any moving frame will show such a difference, no matter whether it is co-moving with elementary particles, rockets, or living beings within rockets.

Another statement of relativity regards the mass. If we measure the mass of some object in a co-moving frame, we will get the same value (its rest mass) at any speed. But measured in a frame resting on the earth, the mass of the object will increase as the velocity of light is approached, just as the mass of the earth will increase as measured in the frame co-moving with this object.

These and some more statements of relativity, awkward as they may appear, are in full agreement with all of our experiments up to now. It has not been possible to check all aspects of the theory in all details, but no experiment, as far as I know, has ever contradicted relativity, while a lot of experiments do contradict classical physics. We should not forget that the idea of a round earth, without people falling "down" on the other side, seemed

just as awkward a while ago. (Again, "down" turned out to be a relative direction instead of an absolute one.)

Experiments have proved the time dilatation, but only in the case where two frames of reference pass one another in unaccelerated flight. No experiments have been possible for the case of returning objects, but they may be possible in future years. Artificial satellites still have velocities much lower than that of light, thus their time dilatation is extremely small. But with the best atomic clocks we could build, it would become just possible to measure the difference. The only problem is how to build such a clock small enough, and capable of working for many years without any maintenance.

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## Flow through a Permeable Membrane

Leslie F. Nims concludes in a recent article [*Science* **137**, 130 (1962)] that "the rate of flow of a tagged species of a material substance through a permeable membrane is proportional to the rate of flow of the substance itself when, and only when, the species mole fraction of the substance is the same on both sides of the barrier." This conclusion is disturbing in view of the common assumption in kinetic experiments "that the flow of tagged material *is* proportional to the flow of normal material" [L. F. Nims, *Yale J. Biol. Med.* **31**, 373 (1959)] (italics mine). Is not the difficulty resolved by precise specification of the meaning of the word *flow* in a given situation?

Thus, Nims's Eq. 1, from Harned and Owen,

$$-\dot{n}_s = \sum_k M_{sk} \frac{\mathrm{d}\mu_k}{\mathrm{d}x}$$

relates to *net* flow of species $s$. Even when derived directly from Newton's laws of motion, *net* flows rather than *unidirectional* flows are involved, since, as Nims has pointed out [*Am. J. Physiol.* **201**, 987 (1961)], it is the "drift velocities of a species" which are being treated rather than "thermal velocities of the individual molecules." Similarly, his Eq. 12

$$(-\dot{n}_{s'} = -N_1\dot{n}_s + M_{ex}RT\frac{\mathrm{d}\ln N_1}{\mathrm{d}x})$$

depends also on the application of the Onsager relation, valid only when fluxes are related to conjugate forces derived from an appropriate dissipation function, which again would involve *net* fluxes.

Accordingly, while Eq. 12 indicates the need for considering the gradient of the mole fraction of a tracer in relating *net* flows of tagged and untagged species, it does not seem to invalidate the common use of tracer isotope to evaluate *unidirectional* flow of untagged substance across a membrane. When tracer is added only to the source side, assumption of equivalent kinetic characteristics of tagged and untagged species implies that every molecule, whether tagged or not, has equal probability of moving completely across the barrier, hence that unidirectional flow of tracer must be proportional to unidirectional flow of untagged substance from source to sink.

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One may assume that material transfer through the membrane of the unit transfer system phase $\alpha$, membrane, phase $\beta$ is accomplished by a two-path-