

# Physics Essays: The Non-Relativistic Paradox of Physical Clock

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## Abstract

Any physical process has temporary extent and can be realized only in case there is time reserve, necessary for it (a time resource). Physical clocks are the only type of devices by means of which we can measure and carry out experimental studies of a phenomenon of a current of physical time. Process of measurements of time intervals by means of clocks also demands expenses of the appropriate time resource for their work. The vicious circle leading to paradox results: we measure time by means of time. This paradox forms basic restrictions on experimental studies of the course of time as physical phenomenon.

**Keywords:** nature of time, nature of physical clocks, variability of systems, special theory of relativity, relativistic clock paradox, general systems theory, temporology, time travel

The understanding of the physical nature of time is one of the most important problems of modern physics. In particular, Lee Smolin believes that all of the mysteries physicists and cosmologists face — from the Big Bang to the future of the universe, from the puzzles of quantum physics to the unification of forces and particles — come down to the nature of time (Smolin, 2013). A large number of researches is devoted to this subject (Reichenbach, 1956, 1958; Whitrow, 1980; Smolin, 2013; Nikolenko, 2013). However after success achieved by the theory of relativity, new fundamental achievements in this area aren't present so far. We are still far from its decision.

The only physical device by means of which we can experimentally investigate this puzzle and receive quantitative results, are physical clocks. Einstein once said: "Time is what clocks measure". Despite a big variety of physical realization, their use as physical device for measurement of the course of time it wasn't called in question.

At the same time the careful analysis of the physical principles of their work leads to an unexpected conclusion — there is a basic problem limiting them ability to measurement of characteristics of the course of time. This problem is a subject of this research.

The nature of a current of time is closely connected with variability of physical systems.

**Definition 1. Variability.** Under term "variability", we will understand the ability of system  $S$  to be in different states  $S_i$  from a set of states  $L$ .

In other words, any physical system  $S$  has variability, if we can name at least two its inner states,  $S_i$  and  $S_j$ , and there is a procedure that allows differentiating them one from another. Let us denote this situation as  $\text{var } S = 1$ , and, which is equivalent,  $\text{var } S \neq 0$ . We will be stating that system  $S$  does not possess variability if all its possible inner states are indistinguishable from one another ( $S_i \equiv S_j$  for any  $i$  and  $j$ ). In this case, the system is internally stationary, that is independent from the moment of observation. Let us define this situation  $\text{var } S = 0$ .

**Definition 2. Principle of macrodeterminacy.** Any physical macro system  $S$  for any arbitrarily assigned moment of time  $t$  may be in one and only in one state  $S_i(t) \in L$ .

It will be convenient to understand moment  $t$  as a moment of observation and description of system  $S$ . Roughly said, this principle affirms that in any moment of time there can be made a clear "photo" (a decisive description of instantaneous state) of macro system. The action of macrodeterminacy principle excludes the self-intersection of world lines of the particles, "protruding" them along time axis and installing in this way a univocal correspondence between the points of time axis and states of the system. This conclusion directly follows from features of a metrics of pseudoeuclidean space-time (Landau & Lifshits, 1975).

If at moments  $t_i$  and  $t_j$  system was in different states  $S_i$  and  $S_j$ , variability of system will be noted as  $\text{var } S(t_j - t_i) = \text{var } S(\Delta t_j)$ . For the ease of convenience when it comes to variability of the system we will consider its edge states in time interval to compose a time interval  $\Delta t$ . As follows from the principle of macrodeterminacy,  $\text{var } S(t) = 0$ . Indeed, at any separate moment of time the system equals itself, as the result of which its variability equals zero. The principle of macrodeterminacy leads to emergence of paradox of time travel (Nikolenko, 2015).

Variability of any closed system is always a result of realization of one or another process in it.

**Definition 3. Process.** We will understand process  $P$  as a sequence of cause-related events unfolding in time.

Realization of process  $P$  in system  $S$  gives rise to a sequence of states of system  $P$ :  $S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow \dots S_i \rightarrow \dots$

**Definition 4. Time resource.** Non-zero time interval, related to realization of any process; we will call it time resource  $\Delta t$ .

Let us assume that system  $S$  transfers from state  $S_i$  into other state  $S_j$  in the result of a certain process  $P$ . As according to principle of macrodeterminacy different moments of time  $t_i$  and  $t_j$  are equivalent to these different states, then interval  $t_i - t_j = \Delta t \neq 0$ . This interval is a time resource, needed for realization of process  $P$ .

**Statement 1.** Any process may be realized only in case of presence of necessary non-zero time resource  $\Delta t$ .

Let us suppose the opposite. May there be process  $P'$ , that transfers system  $S$  from state  $S_i$  to other state  $S_j$  without using the time resource (that is  $t_i - t_j = \Delta t = 0$ ). In this case, there should exist moment  $t$ , a moment, to which correspond different states  $S_i$  and  $S_j$ . However, this directly contradicts the principle of macrodeterminacy, which proves this statement.

We will emphasize that a time resource – the only type of resources necessary for all without exception of physical processes.

We will consider work of clocks from this point of view. The course any clocks, irrespective of their design, is a physical process. According to the Statement 1 the appropriate time resource is necessary for realization of this process. And here we run into a paradoxical situation: to measure course of time we need a time resource. But also course of time and the time resource necessary for work of clocks are set by means of the same intervals of time. Thus, we get to a vicious circle! A measurand - time is appears simultaneously by a time resource necessary for implementation of measuring of this size by means of clock.

Paradox in that we try to measure time by time.

We will consider the situation connected with change of rates of a current of time (for example, in the moving rocket). For measurement of duration of some process happening in the rocket, the traveler uses the clocks which are in the same rocket. We will designate duration of the measured process as  $\Delta t$  (the measurable quantity). Measuring of duration consists of generation by the clock of sequence consisting of  $n$  impulses. Impulses follow through single intervals of time  $\Delta\tau$  (time resource necessary for counting of a single interval of time). The clock will show the next value of duration of process:

$$n = \frac{\Delta t}{\Delta\tau}. \quad (1)$$

Let as a result of action of some factors (for example, changes of gravitational potential) rate of a current of time changed. In this case the measured duration of process will change in  $k$  of times and will make  $\Delta t'$ :

$$\Delta t' = k\Delta t. \quad (2)$$

However as a result of action of the considered paradox also the time resource necessary for process of measurement of duration similarly will change. It can be taken into account as follows:

$$\Delta\tau' = k\Delta\tau. \quad (3)$$

We will consider the equations (1), (2), (3). Consequently, the new value of the duration of  $n'$  shown by the clock is equal:

$$n' = \frac{\Delta t'}{\Delta\tau'} = \frac{k\Delta t}{k\Delta\tau} = n. \quad (4)$$

Thus, a clock appear incapable to show the change of rates of a current of proper time:  $n' = n$ .

The fact of change of rates of the course of time can be established only by comparison of clocks of the rocket with external clocks in an inertial reference system, after return of the traveler from travel to an initial position.

The result received in this work is important for a temporology. A clock is a basic measuring device at research of such physical phenomenon, as a current of time. In addition, a clock is used for all experiments on the study of any dynamic processes. In this regard finding out this paradox requires more attentive analysis of situation at the use of physical clock.

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