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MEMORY EFFECTS IN THE PHYSICAL MANY-BODY SYSTEMS

Historically, memory entity has implied memorization, storage and following individual reproduction processes. I.e., primarily living creatures (human being specifically) are presumed to possess memory.

Meanwhile, quite recently it became obvious that couple of other, very different, objects and systems do possess this (or very similar) property.

First of all, it concerns social systems [1]. Development process of particular group, ethnic group, state and humankind, in general, is defined by the past as well as by the present. In order to understand this, you have to ask yourself one question: "Where this «present» comes from? One second, one hour, one year, several centuries ago?" Even one's experienced moment becomes past immediately.

Besides that, enormous number of non-living nature objects are discovered to have signs of memory. And this fact is no surprise, because, probably, it is difficult to define strict division between the objects of living and non-living character. It is rather artificial and vague [2].

Let's make as example of memory effects creation in physical macroscopic systems. We just mention Boltzman inheritage principle, which was mathematically developed Volterra in the end of XIX century [3]. It's entity is to follows. Let some physical or mechanical process to be defined by influence, i.e., by definition of the function u(τ), $\tau \in (-\infty, t)$. Considered body or system reaction is defined by some V(t) function. In general V(τ) magnitude at present moment of time t is defined not only by magnitude of V(t) at t, but by whole story of changes of V(t) function at abovementioned period of time. They say, V(τ) is functional of V(t). If properties of the material don't change in time, the most formula for functions V(t) is

$$u(t) = V(t) + \lambda \int_0^t K(t-\tau) V(\tau) d\tau. \tag{1}$$

The function $K(t-\tau)$ is the inheritage kernel. It characterized level of «forgetfulness» of those influences at t time, which were made at τ time. Connection laws like (1) define what is called viscoclasticity, viscoplasticity or inherited elasticity in solid state mechanics.

Before that we're discussed macroscopic body of non-living nature. Nevertheless, as recent investigations are discovered, memory effects show up on microscopic (atomic and molecular) level. In principle we can talk of molecular memory. It's presence regulates some peculiarities of the progress of different irreversible processes, for example: magnetic, dielectric, vibrational, structural relaxation, phenomena like viscosity, diffusion, thermoconductivity, etc.

During investigation and description of molecular memory effects most often terms of Markovian and non-Markovian random processes are used. They come to Physics from Mathematics, where they firstly were introduced by Russian scientist Markov in article [4], which was for the first time published in Kazan in the beginning of XX century.

Markovian process is characterized by the fact, that at given time t probability of magnitude of the variable doesn't depend on prehistory system development, but fully depend on the magnitude of the variable at present time. Processes, which post-influence effects are seen, are referred to non-Markovian as well. This incorporates with the fact that state of the system is defined by its whole evaluation from initial to final state.

The mathematical basis for constructing such equations was laid in the works Zwanzig [5] and Mori [6]. The developed procedure allows them to build for the study of the time correlation function $a(t)$ an infinite chain of coupled non-Markovian kinetic equations of the following form

$$\frac{da}{dt} = -\Omega_0^2 \int_0^t M_1(\tau) a(t-\tau) d\tau, \tag{2}$$

$$\frac{dM_1}{dt} = -\Omega_1^2 \int_0^t M_2(\tau) M_1(t-\tau) d\tau, \ldots$$

Where $M_i(\tau)$ - i-th order memory functions, taking into account the effects of molecular memory.

The main problem with this approach is how to closure of an infinite chain of kinetic equations. For this purpose, the memory model functions, mode-coupling approximation of interacting modes, correlation and quasi-hydrodynamic approximation, as well as self-consistent approach generalizing some of them [7-11].

The results of the research allowed, in particular, to explain a number of different flow characteristics of irreversible processes: magnetic, dielectric, vibrational, structural relaxation, as well as phenomena such as viscosity, diffusion, thermal conductivity, and many others (see, for example, references in [11]).

Moreover, currently non-Markovian approach is becoming increasingly common, not only in physics but also in several other areas of human knowledge, such as chemistry, biology, medicine, geology, etc. This allowed the authors of [12, 13] to call it a new scientific paradigm.

References:

1. Gumilev L.N. Tysjacheletie vokrug Kaspija. - M.: Ajris-Press, 2013. - 384s.
2. Ciolkovskij K.E. Monizm vselennoj. - Kaluga: izdanie avt., 1923. - 85s.
3. Volterra V. Theory of permutable function. - Princeton: Princeton University Press, 1915. - 66p.

4. Markov A.A. Rasprostranenie zakonov bolshih chisel na velichiny, zavisjashhie drug ot druga // Izvestija fiz.-mat. obshhestva Kazanskogo un-ta. - 1906. - T.15, №4. - S.135-156.
5. Zwanzig R. Memory effects in irreversible thermodynamics // Physical Review. - 1961. - V.124, №5. - P.983-992.
6. Mori H. A continued fraction representation of the time-correlation function // Progress of Theoretical Physics. - 1965. - V.34, №3. - P.765-776.
7. Shurygin V.Yu., Yulmetyev R. M. Vychislenie dinamicheskogo strukturnogo faktora zhidkosti metodom sokrashhennogo opisanija // Zhurnal eksperimentalnoj i teoreticheskoj fiziki. - 1989. - T. 96, №. 3. - S. 938-947.
8. Shurygin V.Yu., Yulmetyev R.M., Vorobjev V.V. Physical criterion of the degree of non-Markovity of relaxation processes in liquids //Physics Letters A. - 1990. -V. 148, № 3-4. - P. 199-203.
9. Yulmetyev R.M., Yulmetyev T.R., Shurygin V.Yu. Quasihydrodynamic approximation for memory functions in non-Markovian relaxation processes in condensed matter // Physica A. - 1997. - V. 242, № 3-4. - P. 509-521.
10. Yulmetyev R.M., Khusnutdinov N.R., Shurygin V.Yu. Transformation of non-Markovian kinetic equation for TCF to markovian type // Acta Physica Polonica B. - 1999. - V.30, №4. - P. 893-895.
11. Mokshin A.V. Self-consistent approach to the description of relaxation processes in classical multiparticle systems // Theoretical and Mathematical Physics. - 2015. - V.183, №1. - P. 449-477.
12. Azrojanc Je.A., Haritonov A.S., Shelepin L.A. Nemarkovskie processy kak novaja paradigma // Voprosy filosofii. - 1999, № 7. - S.94-104.
13. Shelepin L.A. Stanovlenie novoj paradigmy // Filosofija nauki. - 2001, №.7. - S.24-42.

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