Five Results of M. Apostol

The most important five results I have achieved in my activity of scientific research (1973-2019) in the Institute for Physics and Nuclear Engineering, Institute of Atomic Physics at Magurele responded to problems deemed as fundamental in Physics or formulated and solved new problems which seem to be fundamental, either by extending much our knowledge or by having important practical, applicative consequences.

1. Formation of the solid matter (chemical bonding)

Problem: How N atoms (molecules) make a bound state?

This is a very old problem, one of the greatest problems in Physics. According to Dirac, the laws of the Quantum Mechanics should suffice (and be necessary) for solving this problem. To this end, Pople invented the "wave-function method" (starting 1940, stimulated by the advent of the electronic computers) and Kohn invented the "density functional method" (starting about 1960, which also makes use extensively by numerical computing). Both methods failed, though in current use. Arbitrary parameters are introduced in both methods, needed to "stabilize" the numerical codes. Without such ad-hoc, arbitrary interventions, these methods fail, *i.e.* they do not lead to a bound state. Pople and Kohn received the Nobel prize for these "methods".

About 2000 I. Morjan asked me to solve this problem, in connection with the interest in epoch for atomic clusters and nanostructures.

The problem was solved by **L. C. Cune and M. Apostol, "Ground-state energy and geometric magic numbers for homo-atomic metallic clusters", Phys. Lett. A273 117 (2000)**. Its solution was the PhD thesis of Cune. Authors's contribution is 50-50%.

The solution is given by the so-called "quasi-classical approximation" for the electrons and ions with Coulomb interaction. It is necessary, indeed, to use the quantum-mechanical nature of the electrons, according to Dirac, as expected. The essence of the solution consists in the well-conducted "quasi-classical approximation". In this context, "the quasi-classical approximation" is not an approximation anymore, it is an exact solution, within the limits of the problem. For practical application of the solution modest numerical resources are needed.

2. Pulse thermoelectricity

Problem: Can a thermoelectric generator operate in pulses? With what efficiency?

This is a new problem, brought to my knowledge by M. Nedelcu. It seems that Nedelcu knew about it from an obscure american inventor.

In **M. Apostol and M. Nedelcu, "Pulsed thermoelectricity", J. Appl. Phys. 108 023702 (2010)** it was shown that pulse thermoelectricity is possible and its efficiency is great. The usual thermoelectric generators have a very small efficiency (5-6%), because of the great thermoconductivity.

This obstacle cannot be overcome, neither by materials, nor by generators with special structures. In pulse thermoelectricity the generation of the electricity and the electric and thermal conduction are completely different from the usual generators. For defining the phenomenon a completely new formulation of the themoelectricity was needed (and, in general, of the transport phenomena). It was shown that the efficiency of the pulse thermoelectricity may go up close to the ideal efficiency (close to the efficiency of the Carnot cycle, *e.g.* 30%). It seems that there exist experimental confirmations. Authors's contribution is Apostol theory, Nedelcu experiment.

It is a new phenomenon, a completely new theory, with very promising applications. The "core" of the theory of pulse transport is the diffusion theory.

3. Induced-polarization resonant force

Problem: Does exist a polarization-induced resonant force?

The problem is completely new and very important. If the answer is positive, great (resonant) forces may appear, which may be important in surprising situations. The problem was brought to my knowledge by my coworkers from the scientific research company MiraTelecom (of course, not in these terms; they showed me a strange phenomenon, unexplained, deemed as inexplicable, impossible). In **M. Apostol, S. Ilie, A. Petrut, M. Savu and S. Toba, "A generalization of the dipolar force", J. Appl. Phys. 112 024905 (2012)** the problem was formulated and the polarization-induced resonant force was shown to exist. This is a new and fundamental problem in classical Electromagnetism, with major applications (amongst others, I used the solution to explain the phenomenon called surface enhanced Raman scattering, which was deemed as a "mistery" since its discovery in the '70). The paper quoted above is a theoretical paper, so it may be "reproached" to me exclusively.

4. Turbulence

Problem: How do the vortices appear in the fluid flows?

This is deemed as one of the biggest problem in Physics. S. Talpos brought to my knowledge an attempt of solution. In **S. Talpos and M. Apostol, "Displaced logarithmic profile of the velocity distribution in the boundary layer of a turbulent flow over an unbonded flat surface", Phys. Lett. A379 3102 (2015)** the solution was given. The solution starts with Taylor's statistical theory of turbulence from 1935 and makes use of a smooth-functions perturbation technique for solving the Reynolds equations. In particular, a well-known case of "inverse wind" was solved, which is a typical, well-formed vortex (the so-called boundary layer turbulence). Authors's contribution is 50-50%.

5. Coherent polarization domains in matter

Problem: Is it possible to exist a spotaneous electrical polarization of matter?

This problem was raised, more or less clearly, by many. E. Preoteasa brought

it to my knowledge. At the first sight it looks like a curiosity, rather a "joke", though it is intriguing. If, nevertheless, the answer would be positive, then new fundamental phenomena would appear in matter (spontaneous electrical polarization). This is distinct from ferroelectricity, where pre-existant polarization gets ordered. It was shown that spontaneous polarization domains may appear in matter if the polarization is coherent; it was shown that the polarization may be coherent; it was shown that the problem is related to super-radiance and, basically, it is the problem of the laser effect. There exist three so-called theories of the laser effect, but none answers the question of how the laser effect is possible. According to these theories the answer would be given by the solution of some non-linear evolution equations. The solution was given by **M. Apostol "Coherence domains in matter interacting with radiation", Phys. Lett. A373 379 (2009).**