CREATIVITY LEADING TO DISCOVERIES IN PARTICLE PHYSICS AND RELATIVITY

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Abstract

 Independently on Popper’s, Holten’s and Kuhn’s philosophy of science, we present – in “annis mirabiliss 2005” – the basic ingredients of discovery creativity in physics. We discuss understanding, problem solving, heuristics, computer thinking, technological thinking and so on. We present some discoveries from the viewpoint of creativity. The Dirac equation, the Riccati equation for massive photons in laser physics, the nonlinear Schrödinger equation and its classical limit for heavy particles, the quantum Navier-Stokes equation, the equation of the quantum magneto-hydrodynamics and so on. We discuss general relativity, the nonlinear Lorentz transformation involving the maximal acceleration constant which we relate to the Hagedorn temperature, and possible dependence of mass on acceleration. We discuss the reciprocity of technology and theoretical physics and the technological limit.

1 Introduction

Michael Faraday – man of simplicity – used special experimental methods to discovery many laws of nature including famous magnetic induction. Thomas Alva Edison used specific experimental techniques and method ”trial and error” to generate inventions useful for daily life. Nicola Tesla invented electrical motor for alternate current. Euler, Poincaré, and others realized mathematical discoveries every day. All these thinkers used undoubtedly some heuristical rules, or “road map” to achieve success.
What are the dominating factors which determine the discoveries and the key discoveries? What are the specific steps? What are the tenacious ideas, or, purposes which are leading to the key discoveries?

The principles of discoveries are not always accepted by physicists. Why? Because we are in a jungle of facts and the only way forwards we built is the way by trial and error.

On the other hand, if we want to avoid disappearing of the total or partial content of the classical physics in the new theory it is desirable only small change of the classical theory and to built the new theory as a paradigm of the old theory. Such a principle was used by Bohr in his planetary model of atom. However, de Broglie and Schrödinger deflected from the Bohr instructions. Similarly, in particle physics, quark theory – nuclear aristocracy – is not small change of the bootstrap theory – nuclear democracy –, but revolution.

The integral part of the process of discoveries is, no doubt, also an effort of the nameless and godforsaken investigators who prepared the way to a discovery. In the scope of this process a discoverer appears as a single man among a large team of scholars who has completed the initiated work.

We know from history (Hadamard, 1946) that the predecessor of the infinitesimal calculus was Nicole Oresme (1323-1382), Johann Kepler (1571-1630) and Pierre Fermat (1601-1665), the author of well-known famous theorem. Fermat received the mathematical expression for the condition of maximum and minimum of a function. He constructed expression

\[
\frac{f(a + \varepsilon) - f(a)}{\varepsilon}, \quad \varepsilon \to 0.
\]  

However, this expression is nothing else than the derivative of \(f(x)\) at point \(x = a\), and Fermat also applied it to finding tangents to several curves. However, nor Fermat was able to overcome an unknown barrier standing at the way to the infinitesimal calculus (Hadamard, 1946). Oresme, Kepler and Fermat realized only the first step of the creation of the infinitesimal calculus.

It is necessary to distinguish two steps (Hadamard, 1946).

“To discover a fact on the one hand, and to understand the significance of this fact on the other hand”.

When Newton and Leibniz appeared in the sky of mathematics, the infinitesimal calculus was realized. While Fermat applied his method for special examples, Newton and Leibniz gave a precise form to that idea, in driving it far enough to be able to make it a starting point for further researches.

The decisive factors of the birth of the infinitesimal calculus were the definition of the notion of derivative, which is of course not sufficient, and the application of this mathematical object to the large amount of problems. Thus, the discovery of infinitesimal calculus was based, as we can deduce, on the two general principles. Introducing the new notion and its large application.

The misunderstanding of the significance of the fact is well know in particle physics where the so called \(\Omega^-\)-meson was predicted in 1962 as the crucial test of the \(SU(3)\) symmetry and discovered in Brookhaven in 1964. However, already in 1954 Eisenberg had observed \(\Omega^-\)-meson and in 1955 it was confirmed by Fry. The laboratory events was interpreted as the \(\Omega^-\) events and not as the \(\Omega^-\)-meson. The experimenters were not prepared to understand the significance of the discovery of the new particle (Alvarez,
Similar events in the particle physics related to the Popper philosophy of discoveries was presented in the Pietschmann (1978) article.

At present time the excited states of proton is the brilliant confirmation of the quark composition of proton. But the society consciousness hesitates in understanding of this fact. The excited states of an electron is the manifestation of its substructure but the society consciousness hesitates in understanding of the significance of this fact.

In physics, Bohr created a model of atom bearing later his name. Bohr created two postulates which define the model of atom: 1. every atom can exist in the discrete series of states in which electrons do not radiate even if they are moving at acceleration (the postulate of the stationary states), 2. transiting electron from the one stationary state to other emits energy according to the law

\[ h\omega = E_m - E_n, \] (2)

where \( E_m \) is the energy of an electron in the initial state, and \( E_n \) is the energy of the final state of an electron to which the transition is made and \( E_m > E_n \). This postulate involves also the assumption that the photons are created by transitions and they exists only outside of atom. Photons are real particles, real quanta as was confirmed by the Compton effect. There is no photon inside the atom. The multiphoton Compton effect is also possible as follows from the Feynman diagrams, or from the Volkov solution of the Dirac equation (Berestetzkii, 1989; Pardy, 2003a, 2003d, 2004b). This effect was verified by high energy laser experiments.

The photon situation is reciprocal to the quark situation in particle physics. Quarks exist only inside the mesons and baryons. New mesons, or baryons are created and cloned inside mesons and baryons by the tension of the physical strings connecting quarks. The existence of quarks inside mesons and hadrons was verified by many deep inelastic scattering experiments.

The Planck distribution law of photons inside the so called black body was derived by Einstein from the Bohr model. Einstein introduced coefficients of spontaneous and stimulated emission \( A_{mn}, B_{mn}, B_{nm} \). From the condition of equilibrium

\[ N_mA_{mn} + N_m\varrho\omega B_{mn} = N_n\varrho\omega B_{nm} \] (3)

and the Maxwell statistics

\[ N_m = D e^{-\frac{E_m}{kT}}, \quad N_n = D e^{-\frac{E_n}{kT}}, \] (4)

he derived the Planck law in the form:

\[ \varrho\omega = \frac{\hbar \omega^3}{\pi^2 c^3} \frac{1}{e^{\frac{\hbar \omega}{kT}} - 1}. \] (5)

The decisive point of the derivation of the black body by Einstein was not the mathematical beauty of the equations but specific model suggested by intuition.

However, the Einstein derivation was not complete, because he did not consider the situation that the black body can be influenced by some external field. Then, it is necessary to introduce coefficients of the external influence \( C_{mn}, C_{nm} \), and from the equilibrium condition to derive the generalized Planck law (Pardy, 2005c).

\[ \varrho\omega = \frac{\hbar \omega^3}{\pi^2 c^3} \frac{1}{e^{\frac{\hbar \omega}{kT}} - 1} + \frac{\hbar \omega^3}{\pi^2 c^3} \frac{P(\omega) - Q(\omega) e^{\frac{\hbar \omega}{kT}}}{e^{\frac{\hbar \omega}{kT}} - 1} \] (6)
where $P, Q$ are some function which must be calculated using the advanced solid state physics and advanced quantum mechanics.

In the special theory of relativity, Einstein was not influenced by the partial results of his predecessors. Namely by, W. Voight (1850-1919) who proposed in the year 1887 an idea of the transformation of coordinates and time, J. Larmor who in 1900 derived independently so called Lorentz transformation and H. Poincaré (1854-1912) who derived in 1905 the similar consequences as Einstein.

Einstein worked independently. The dominating factors leading Einstein to his theory were admiration of the axiomatic system of Euclidean geometry, with the goal to unify the electromagnetism and moving bodies by the axiomatic way, and a courage to postulate a principle of constant light velocity as the integral part of his axiomatic system. This principle is from the viewpoint of common sense, very strange and nobody was of a courage to postulate such strange principle. **Einstein decided to hit the nail on the head.**

The reasonable generalization of the special theory of relativity for noninertial systems and gravity, respectively, was a theory working with the non-Euclidean mathematical objects. Einstein decided to apply the Riemann geometry which was yet developed by B. Riemann (1826-1866) and T. Levi-Civita (1873-1941).

Dominating heuristic factors in the birth of the general relativity theory were the Einstein goal to unify STR and gravity. Later, Hilbert proved that Einstein gravity equations could be easily derived from variation principle with the adequate Lagrangian. Why was not so easy to create general relativity? Leibniz, Kant, Schopenhauer and others created the statements that space and time is only the subjective feelings, or, á priori auxiliary notions, and not objective reality. Lobachevskii and Gauss introduced space and time as physical reality. This was the starting point of the modern science of space and time and of the Einstein general relativity.

Now, let us look more to creativity in theoretical physics leading to discoveries.

## 2 On creativity in general

The theoretical physics was realized by the creative work and not by copying the older physical texts and existing products. The creative work is a novel work. It can be meaningful or meaningless. It is meaningful in the human sense, if it is accepted by the society, or by the specific group of people as useful and valuable work. The "novel work" means that the creative product did not exist previously in the same form. It arises from the already existing material by the process of reorganization, reintegration, modification, new axiomatization, redefinition of basic parts and so on, in such a way that when it is completed it contains elements that are new. The novelty of the creative work is given by the novelty of methods and ideas used and by the deviation from the traditional knowledge or the status quo. The novelty of the creative work depends usually on the novelty of the problem and especially on the creative individual. The creative individual has the specific motivation to create. The creativity motivation does not differ from any motivation problem. In other words, the individual experiences a state of disequilibrium, or a lack of satisfaction with the existing state of affairs. In such a way the homeostasis of the creative individual is disturbed. This is possible only when there exists the sensitivity to the given state. The creative person has a lower threshold, or the greater sensitivity for the gaps or the lack of closure that exist in the environment (Bodnarczuk, 1990). The sensitivity is obviously given by the intellectual factors, involving fantasy, inborn in the creative person and by the educational drill which cultivate the mental life of a person.
It also means that computer creativity can be only mechanical one and never will involve fantasy, because fantasy cannot be realized by non-stochastic computer algorithm.

Mathematics – art for art – is the science of the pure forms which gives no propositions about outer world. Theoretical physics, is, as can be seen later, the applied pure mathematics. It means that theoretical physics is pure mathematics restricted by the physical experiment and involving physical interpretation.

While mathematician starts from pure definitions and then proceeds to show how the product of thought may originate either by single act of creation or by the double act of positing and combining, the theoretical physicist interprets mathematical definitions (for instance operators in quantum mechanics, Green’s functions in the quantum field theory, and so on) and expresses the outer world in the mathematical form.

However, because the theoretical physicist works practically with the mathematical objects, his thinking is the mathematical one, but limited by the outer world laws. Nevertheless he uses the same heuristics as mathematician. Then, the principles of creativity in mathematics and theoretical physics are practically congruent. The effectiveness of work in physics and mathematics consists in clarification and using these principles.

The interesting is the opinion of Julian Schwinger on the creativity.

”What the physicist actually does? He does not begin with the final theory and draw mathematical consequences, he elaborates the theory, he describes a certain class of phenomena and then extrapolates and sees how far it works”.

Every rigorous scientific work is based on the operative rules which are rigorously defined or are only intuitive ones, for which man failed to obtain a precise algorithm. If we use the intuitive rules in science we say that we use the heuristic procedures. The aim of the heuristic procedures, or the heuristics is to solve new problems for which the algorithmic solutions are not known, or difficult to find, and to make discoveries.

3 On theoretical methods in physics

One can distinguish between two main procedures in theoretical physics. The first one is to work with experimental facts which means the close contact with the experimental physicists. This method involves the systematical collection of the experimental data and trial to fit them into a comprehensive and satisfying scheme.

The other procedure is to work from the mathematical basis. This second method was in the modern physics used in the maximally effective way by P. A. M. Dirac. In this method one examines and criticises the existing theory. One tries to pin-point the faults in it and then tries to remove them by replacing it by the new scheme. The obstacles in the second way consist in removing the faults without destroying the great successes of the existing theory. In other words, the second procedure is the replacing of the one theory by the better one in such a way that the better theory involves some details of the first theory, other details distracts and implants into the new schema some new ideas.

While the first method called phenomenology requires the common sense and not very much mathematics, the second method is only for the mathematical experts who use the mathematics with the goal to understand nature.

The procedure which works from the mathematical basis was sometime also unsuccessful. For instance, the gravitational and the electromagnetic fields should be closely
connected, but Einstein spent many years trying to unify them, without success. Nevertheless it is necessary to say that the Einstein endeavor formed the basis for the unification of electromagnetic and weak interactions and for the struggle to unify the all forces in nature into the grand unification scheme.

Whether one follows the phenomenological or the mathematical procedures depends on the subject of study and on the intellectual mentality of the investigator. Let us illustrated it by the discovery of quantum mechanics (Salam).

While Heisenberg was working from the experimental basis, using the results of spectroscopy which by 1925 had accumulated an enormous amount of experimental data, Schrödinger worked from the mathematical basis. Among these data were some very important, namely the relative intensities of the lines of the multiplets. Only Heisenberg was able to pick up the substantial thing from the great wealth of data and arrange them in a matrix scheme, which led to the matrix quantum mechanics.

On the other hand Schrödinger had the idea at the back of his mind that spectral frequencies should be fixed by eigenvalue equation, something like those that fix the frequencies of system of vibrating strings.

Of course, the Schrödinger spectral idea was an integral part of his intellectual attitude to modern physics especially to the relativity. Schrödinger was influenced by the new physical ideas and so he tried to set up a quantum mechanics within the framework of relativity. While de Broglie applied the wave idea to the free particles, Schrödinger tried to generalize it to an electron bound in atom within the relativistic framework. However, when he applied his theory to the hydrogen atom, he found it did not agree with experiment. The discrepancy was caused by the ignoring the spin of the electron. Then Schrödinger noticed that his theory was correct in the nonrelativistic approximation which forms the well known Schrödinger equation.

4 The Dirac heuristics

Nobel Laureate Abdus Salam says on Dirac (Kamran, 1989):

"Paul Adrien Maurice Dirac was undoubtedly one of the greatest physicists of this or any century. In three decisive years, 1925, 1926 and 1927, with three papers, he laid the foundations first of quantum physics, second of the quantum theory of fields, and third of the theory of elementary particles with his famous equation of the electron. No man except Einstein has such a decisive influence in so short a time on the course of physics in this century".

So, if Dirac is compared with Einstein, then is is worth while to know his heuristic methods in theoretical physics used by him to perform such big discoveries. Many Dirac authentic statements concerning the methods of discoveries in theoretical physics are very useful for understanding his methods of discoveries. Surprising is that Dirac excluded the philosophical thinking in his theoretical works (Kamran, 1989)).

"I then felt that all the things that philosophers said were rather indefinite, and I came to the conclusion eventually that I did not think philosophy could contribute anything to the advance of physics".

6
The basic philosophical question is what does a word mean or what does every phrase in the verbal expression of thought mean? Just such attitude but in the more mathematical form is involved in the Dirac modes of thought.

The very instructive are the Dirac opinions on the Einstein general theory of relativity and on the magnetic monopole (Kamran, 1989).

"One has a great confidence in the theory arising from its great beauty, quite independent of its detailed success”.

".. monopoles should exist, because of pretty mathematics”.

The pretty mathematics is also the integral part of Dirac’s derivation of his famous equation. The heuristic procedure which Dirac used was so called playing with equation. The discovery of the Dirac equation was realized after the Pauli equation which Pauli proposed in May 1927 (Pais, 1986).

The Pauli equation describes the electron spin by the two-component spinors in such a way that spin is explicitly coupled to the electron angular momentum. The strength of the coupling called the ”Thomas factor” cannot be determined inside the Pauli theory and it must be inserted by hand without further justification. Pauli noted that such unpleasant feature is caused by its nonrelativistic behavior. In other words Pauli was award that this equation was approximate and provisional.

The spin was described in the Pauli theory by the 2 x 2 matrices, since known as the the Pauli matrices. However, now it is known that Dirac discovered these independently. Dirac writes (Dirac, 1977b):

"I believe I got these matrices independently of Pauli, and possibly Pauli also got them independently from me”.

However Dirac used matrices of four rows and columns. At this procedure Dirac discovered that his 4 x 4 matrices were composed from the Pauli 2 x 2 matrices.

Thus the Dirac equation was born in 1928 (Dirac, 1928a, 1928b) by respecting the special theory of relativity and using the heuristics linearization of the nonlinear operator. While the rigorous relativistic generalization of the Schrödinger equation is

\[ i\hbar \frac{\partial \psi}{\partial t} = \sqrt{c^2 p^2 + m^2 c^4} \psi. \]  

(7)

Dirac use the matrix transcription where it is possible to write

\[ \sqrt{c^2 p^2 + m^2 c^4} = c \sum_{\mu=1}^{4} \alpha_{\mu} p_{\mu}, \]  

(8)

where \( \alpha_{\mu} \) are composed from Pauli matrices. Dirac did not introduce numbers \( p,q,r,s \) in such a way that \( (a^2 + b^2 + c^2 + d^2) = (pa + qb + rc + sd)^2 \) and did not define special relations between numbers \( p,q,r,s \). He used matrices, because Pauli equation involved matrices and successfully described the quantum nonrelativistic motion an electron. In case of introduction of numbers \( p,q,r,s \), we get the relativistic Schrödinger equation of the first order while Klein-Gordon equation is equation of the second order.

The great Dirac discovery he has made was, that his equation gave the particle a spin of half a quantum. Also gave it a magnetic moment. It gave just the properties of an electron (Dirac, 1977b).
The obvious consequences of the Dirac equation were the Sommerfeld fine structure formula and the Thomas factor. For energies small compared to $mc^2$ all the results of the nonrelativistic Schrödinger theory were recovered.

While at this time the Dirac equation is famous, the serious objections were to this equation at time of its birth. The fundamental objection was the existence of the negative energies of the electrons which followed inevitably from it. Now, they are interpreted as the positron energies, where positron is the antiparticle to electron. Dirac himself supposed that his equation describes proton instead of positron, at this time nondiscovered particle. However, the magnetic moment of proton differs from the Dirac prediction.

Dirac was never satisfied quite with his equation and in year 1972 postulated the new equation with the positive energy solution only (Dirac, 1972a, 1972b, 1977a). Although the new equation is also studied at the present time, it is not so famous as the original equation from year 1928.

So we have seen that the specific principles guiding Dirac to his discovery were the pretty mathematics, playing with equation and the principles of the special theory of relativity. During the discussion with Abraham Pais on the research methods, Dirac said (Pais, 1986):

"First play with pretty mathematics for its own sake, then see whether this leads to new physics".

The method of "playing with mathematics" was the "leitmotiv" of the all Dirac life around. At age 28 he writes (Dirac, 1931):

"The most powerful method of advance that can be suggested at present is to employ all the resources of pure mathematics in attempts to perfect and generalize the mathematical formalism that forms the existing basis of theoretical physics, and after each success in this direction, to try to interpret the new mathematical features in terms of physical entities".

At age 36 Dirac writes (Dirac, 1939):

"As time goes on it becomes increasingly evident that the rules which the mathematician finds interesting are the same as those which Nature has chosen".

At age 60 he writes (Kuhn, 1963):

"I think it’s a peculiarity of myself that I like to play with equations, just looking for beautiful mathematical relations which may be don’t have any physical meaning at all. Sometimes they do".

At age 78 he writes (Dirac, 1982):

"A good deal of my research work in physics has consisted in not setting out to solve some particular problems, but simply examining mathematical quantities of a kind that physicists use and trying to fit them together in an interesting way regardless of application that the work may have. It is simply a research for pretty mathematics. It may turn out later that the work does have an application. Then one has good luck".

8
So we have seen that Dirac was deeply convinced that the best method how to find truth in Nature is the pretty mathematics. So, mathematics is for the physicists not only the instrument of the description of the phenomena, however, it is the main source of ideas and principles of the new theory. With the help of the pure mathematical construction we can find the notions and the relations between them which give us the key in order to understand the phenomena in nature. The experiment remains the only single criterion of the adequacy, or non-adequacy of the mathematical constructions. However, the present creative basis belongs to mathematics.

The foregoing statements do not mean that if one is expert in mathematics, he is at the same time theoretical physicist because there is the substantial difference between mathematics and theoretical physics. While the mathematical statements are according to Bertrand Russell - the greatest philosopher of England - non-existent, the physical statements inform us on the existing relations and things in nature.

The mathematical program can be effective in the theoretical physics if it involves the deep physical principles and ideas. From this point of view it is possible to analyze the effectiveness of such theories as the Regge theory of elementary particles, the bootstrap theory, the supersymmetry, supergravity, source theory, the present time string theory and so on. Only if they are based on the deep physical ideas, then, there is some chance to be physically true.

Let us summarize the discourse on the Dirac heuristics by his own statement (Dirac, 1978).

"I learn to distract all physical concepts as the basis for theory. Instead one should put one’s trust in a mathematical scheme, even if the scheme does not appear at first sight to be connected with physics. The physical meaning had to follow behind the mathematics".

Now, we can show that the Dirac method enables also the playing with his equation itself (Pardy, 1973a). Let us write his equation in the form:

\[ \varphi_1 + \varphi_2 + mc\psi = 0, \]  
(9)

where

\[ \varphi_1 = \hbar \gamma_\mu \frac{\partial \psi}{\partial x_\mu}; \quad \varphi_2 = -ie \frac{A_\mu \gamma_\mu}{c} \psi. \]
(10)

We can multiply the last equation from the left by gamma-matrices \( \Gamma \) an by the conjugated function \( \bar{\psi} = \psi^+ \gamma_4 = (\psi^*_1, \psi^*_2, \psi^*_3, \psi^*_4, \) in order to get:

\[ \bar{\psi} \Gamma_\alpha (\varphi_1 + \varphi_2 + mc\psi) = 0, \]
(11)

where

\[ \gamma_\alpha = I, \gamma_\mu, \sigma_{\mu\nu}, i\gamma_5 \gamma_\mu, \gamma_5 \]
(12)

with

\[ \sigma_{\mu\nu} = \frac{1}{2i}(\gamma_\mu \gamma_\nu - \gamma_\nu \gamma_\mu). \]
(13)
It is possible to show that the equation (11) is equivalent to the Dirac equation (Pardy, 1973a). Its mathematical beauty corresponds to the beauty of the Dirac equation.

The meaning of the above procedure is, that electron can be evidently described by the components $\bar{\psi} \Gamma_\alpha \psi$. It is possible to derive the Lorentz equation for the classical motion of a point particle in the electromagnetic field for the component $\bar{\psi} \gamma_\mu \psi$. The so called Bargmann-Michel-Telegdi spin equation follows for the component $\bar{\psi} \gamma_\mu \gamma_5 \psi$ (Rafanelli et al. 1964; Pardy, 1973a). The procedure performed with Dirac equation can be applied in the analogical form to the Duffin-Kemmer equation (Pardy, 1973b).

There is a case when Dirac equation generates new equation. We think the case of the Volkov solution of the Dirac equation for an electron moving in the electromagnetic field of massive photons. While in case for the massless photons the solution is known, the massive photon situation leads to the so called Riccati equation (Par dy, 2003d, 2004d)

$$y' + y^2 + P(x) = 0, \quad (14)$$

where the function $y$ is the integral part of the spinor $\psi$. So, the Dirac equation generates the new differential equation which, as it is known, has no solution in the closed form in general. The Riccati equation was mathematically meaningful from the time of its discovery. Now, it is meaningful also from the viewpoint of physics (Pardy, 2004d).

It can be easily seen that the playing with equation and with mathematics of the nonrelativistic quantum mechanics leads to the new generalized quantum mechanical equation of the nonrelativistic quantum mechanics. Let us demonstrate it here.

If we add to the original equations of hydrodynamical model of quantum mechanics (Pardy, 2001d) the classical terms from the hydrodynamics involving the viscous properties of a fluid, then we get the following evidently the beautiful quantum Navier-Stokes equations:

$$m \left( \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} \right) = -m \nabla V_q - \frac{1}{n} \nabla p + \frac{\eta}{n} \Delta \mathbf{v} + \frac{1}{n} \left( \xi + \frac{\eta}{3} \right) \text{grad div } \mathbf{v}, \quad (15)$$

where $V_q$ is the known quantum mechanical potential:

$$V_q = -\frac{\hbar^2}{2m} \frac{\Delta \sqrt{n}}{\sqrt{n}}. \quad (16)$$

and potential $V$ is replaced by the macroscopic pressure $p$.

This equation (15) can be considered as the quantum mechanical model of the quantum process involving dissipation. We hope that this equation will be confirmed by experiment and then it will be of the same value as the original Schrödinger equation of the quantum mechanics.

The second possibility of the method of playing with equation is the equation of the so-called quantum magneto-hydrodynamics which can be easily obtained from the modification of the quantum hydrodynamical equation (Madelung, 1926) inserting in it the magneto-hydrodynamical term. The result is the following equation:

$$m \left( \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} \right) = -m \nabla V_q - \frac{1}{n} \nabla p + \frac{1}{4\pi n} (\text{rot } \mathbf{H} \times \mathbf{H}), \quad (17)$$

where and $\mathbf{H}$ is the vector of the magnetic field. The last equation involves quantum corrections to the classical magneto-hydrodynamical equation. The Alfvén waves follows
for instance form the magneto-hydrodynamical equation. It means that equation (17) involves the quantum corrections to the Alfvén waves.

The dissipative terms can be evidently inserted in the equation (17) in order to get quantum Navier-Stokes magneto-hydrodynamical equation.

\[
m \left( \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v} \right) = -m\nabla V_q - \frac{1}{n}\nabla p + \frac{\eta}{n}\Delta\mathbf{v} + \frac{1}{n} \left( \xi + \frac{\eta}{3} \right) \text{grad div } \mathbf{v} + \frac{1}{4\pi n} \left( \text{rot } \mathbf{H} \times \mathbf{H} \right).
\] (18)

Now, let us consider the so called nonlinear Schrödinger equation and its solution. It was shown that it was also derived by the method of playing with equation (Pardy, 2001d).

The motivation for introduction of the nonlinear quantum theory was in expecting of the better understanding of the synergism of waves and particles. Bialynicky-Birula and Mycielski (1976) considered the generalized Schrödinger equation with the additional term \(F(|\Psi|^2)\Psi\), where \(F\) was some arbitrary function which they later specified to be \(-b(\ln |\Psi|^2)\) as a consequence of the factorization of the wave function for the composed systems. The same equation was also obtained by Lemos (1983) within the context of the stochastic quantum mechanics. Using the method of playing with equation, we derived the generalized Schrödinger equation as follows (Pardy, 2001d).

\[
i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m}\Delta \Psi + V\Psi - b(\ln |\Psi|^2)\Psi,
\] (19)

where \(b\) is positive and the nonlinear term contents the unit constant with the dimensionality of \((\text{length})^3\).

It is easy to show that eq. (19) follows from the hydrodynamical model of quantum mechanics (Bohm et al., 1954; Madelung, 1926; Rosen, 1974) after adding into the Euler hydrodynamical equation the pressure \(-b|\Psi|^2\) and by the inverse procedure to the derivation of the hydrodynamical model (Pardy, 2001d).

The solution of eq. (19) can be assumed in the soliton-wave form (in the one-dimensional case with \(V = 0\)) (Pardy, 1994a; Pardy, 2001d):

\[
\Psi(x, t) = cG(x - vt)e^{i(kx - \omega t)},
\] (20)

where \(c, v, k\) and \(\omega\) are real numbers. After insertion of function (20) into eq. (19), we get

\[
\Psi(x, t) = ce^{a/B} \exp \left\{ -\left[ \frac{1}{4}B(x - vt + d)^2 \right] \right\} e^{i(kx - \omega t)},
\] (21)

where

\[
v = \frac{\hbar k}{m}, B = \frac{4mb}{\hbar^2},
\] (22)

and

\[
a = B - \frac{2m}{\hbar} \omega + k^2 - \frac{2m}{\hbar^2}b\ln c^2,
\] (23)

with \(d\) being some constant. The constant \(c\) can be determined from the normalization condition.
\[ \int_{-\infty}^{\infty} \Psi^* \Psi \, dx = 1. \] (24)

The probability density is \( \delta_m(\xi) = \Psi^* \Psi \), and from eq. (21) we get (for \( d = 0 \))
\[ \delta_m(\xi) = \sqrt{\frac{ma}{\pi}} e^{-\alpha m \xi^2}, \quad \xi = x - vt, \quad \alpha = \frac{2b}{\hbar^2}. \] (25)

It is obvious that \( \delta_m(\xi) \) is the delta-generation function, which tends for \( m \to \infty \) just to the Dirac delta function. The advantage of the \( \delta_m \) function is in its behavior for the sufficiently the large mass \( m \), because in this case it describes the strongly localized motion of a particle. In other words, function \( \delta_m \) describes the classical motion of a particle with large mass \( m \) in contrast to the standard quantum mechanics. Such behavior obviously gives the logical support for the competence of the logarithmic quantum mechanics.

Other interesting feature of the nonlinear QM consists in fact that it solves the Schrödinger cat as a consequence of the broken principle of superposition (Pardy, 2001d).

If the nonlinearity in the Schrödinger equation is of the quadratic form (Pardy, 1989b), we get so called Gross-Pitaevskii equation
\[ i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m} \Delta \Psi + V \Psi - \alpha |\Psi|^2 \Psi, \] (26)
which describes the quantum motion of superfluid described in many articles including author’s one (Pardy, 1989b).

5 The problem of understanding of mathematics and physics

The high creativity in mathematics, physics, or in other sciences is based on the deep understanding of the content and techniques used. The creativity without understanding is a free play with the mathematical or theoretical objects, but giving nothing interesting. Only understanding of the scientific disciplines gives the interesting and valuable results. However, what is the understanding as such? Especially what is the understanding of mathematics or theoretical physics? Let us try to answer this question.

Understanding in science, especially in physics, involves the knowledge of explanation of a fact, prediction of new consequences of it and knowledge of possible applications.

Paul Ehrenfest (Weisskopf, 1971):

“refused to admit that something is understud if one understands only the mathematical derivation”

Or, another statement of Ehrenfest (Weisskopf, 1971):

"Physics is simple but subtle”

In case we consider some physical effect, the understanding of this effect means how does the effect arise, what are the general causes of it and how it is related to the other part of nature.
Let us imagine a long series of syllogisms with components $A$, $B$, $C$, ..., in which the conclusions of those that precede form the premises of those that follow. Or, it is obvious that everybody intelligent person is able to grasp the syllogism in the isolated form, or, in the form $A \implies B; \quad B \implies C; \quad C \implies D; \quad \ldots \implies END$.

However, between the moment when a man meets the first proposition and the END much time will sometime have elapsed and it may well happen that a man has been influenced by some unexpectable events which change the meaning of the individual steps and also the meaning of the whole chain. In such a way the chain of syllogisms forms no harmonic system for a man and the subjective reflection of such situation is the feeling of some misunderstanding. In other words understanding supposes not only knowledge and understanding of the individual steps but the simultaneous retaining them in the memory in the original chain. From these words it follows that people who have weak mathematical memory are not able to grasp the total chain of the mathematical steps and therefore are not able to understand mathematics. On the other hand the computer calculations inform us that the true results can be obtained without understanding in the human sense because computer works algorithmically without understanding.

After analysis of the notion understanding we have found miscellaneous view on the notion of understanding. For instance:

a) understanding means to see the premises from which the theory arises, what are the fundamental results of the theory and the method used
b) understanding means the knowledge of logical systematization
c) understanding is the knowledge of the model of the system or situation
d) understanding means the knowledge of the operational system of the theory and its physical meaning
e) understanding is process which is tested by the ability of solving physical problems of given theory
f) understanding means ability of formulation of the new problems
g) understanding means the knowledge of all questions formulated in the boundaries of the given theory

and so on. It is obvious that it is possible to create other definitions of understanding which stress specific aspects of process of understanding.

Understanding can be tested by explanation. What is explanation? It is the verbal process which can be no more then a description which simplify. It describes situation in terms of fundamental factors, being so fundamental that no description of them is possible. The fundamental factors called "absolute" may be given names and the number of them should be a minimum. The explanation involves understanding and should employ only such conceptions which are in common use. It is essential that the explanation must be logically correct and actually true. It is well known from the pedagogical practice that the explanation of the unknown object can be realized easily by exemplification.

According to Poincaré (1913), understanding in mathematics appears as sudden illumination. However, it is not absolutely spontaneous, but appears as a result of the long course of the previous work.

The integral part of understanding is the feeling of harmony which form a internal signal informing us on understanding of the mathematical or the physical system of ideas.
If a man feels during the cognitive process certain disharmony, then this is the signal informing him on the necessity to analyze the problem once again.

At present time, the **time of the artificial intelligence**, the question arises how to realize explanation with so called computer understanding of the problem situation, and how to make predictions by computer by pure deductive algorithm. For prediction, it is the **logical process which is equivalent to mathematical deduction**. Inductive predictions are not valid because the results of induction are hypotheses which must be proved. We believe that it is possible to solve the general problems by computer and also to produce problems by computer.

### 5.1 Understanding of relativity

The special theory of relativity has familiarized us with the notion of thinking of space-time in terms of geometry. In other words we describe space-time as a differential manifold endowed with the Minkowski metric

\[
 ds^2 = c^2 dt^2 - (dx^2 + dy^2 + dz^2). \tag{27}
\]

Putting

\[
 t = t(x_1, x_2, x_3, x_4); x = x(x_1, x_2, x_3, x_4); y = y(x_1, x_2, x_3, x_4); z = z(x_1, x_2, x_3, x_4), \tag{28}
\]

we get after insertion of the transformations (28) into the space-time element (27):

\[
 ds^2 = g_{\mu\nu} dx_\mu dx_\nu, \tag{29}
\]

which is equivalent to the original element (27). The coefficients \( g_{\mu\nu} \) form the so called metric tensor. It is determined unambiguously by the transformations (28). It is possible to show that if we choose the metric tensor arbitrarily, then there is no transformations of the form (28), from which the coefficients \( g_{\mu\nu} \) follow. The form (29) in this case defines so called Riemann geometry. The Einstein idea consists in the assumption that the space-time in the presence of the gravitational field is not Euclidean but Riemannian and that the motion of a body in the gravitational field is equivalent to the motion of the same body in the Riemann space-time along the geodesic path which is described by the equation

\[
 \frac{d^2 x^\mu}{ds^2} = \Gamma^\mu_{\alpha\beta} \frac{dx^\alpha}{ds} \frac{dx^\beta}{ds}, \tag{30}
\]

where \( \Gamma^\mu_{\alpha\beta} \) are so called the Christoffel symbols and they are dependent on \( g_{\mu\nu} \). The geodesic path can be defined also mechanically in the 2D-geometry as a trajectory of the infinitesimal roller skate moving on the 2D-surface. The definition of the mechanical infinitesimal roller skate in the 4D-surface was not given till present time.

Why did Einstein used the Riemann geometry and not the different approach? From the history of mathematics it is known that Gauss (1777-1855), and also Lobatchevskii (1792-1850) considered space and time as the objective reality and created the philosophical idea that the geometry of space is determined by the physical properties of it. Or, it may not be necessary Euclidean. Later Riemann (1826-1866) created geometry of his name. So the idea that space, or, space-time can be curved was not new and Einstein was free to accept the physical idea that the curvature of space-time is caused by gravity.
In case that the transformations (28) do not involve time, we get eq. (30) in the three-dimensional form with \( ds = dt \) and then they are equivalent to the Lagrange equations. They are involved in the every textbooks on the tensor calculus.

The metric tensor \( g^{\mu \nu} \) in the general theory of relativity and gravitation can be determined by solution of the Einstein equation

\[
R^{\mu \nu} - \frac{1}{2} g^{\mu \nu} R = (8 \pi G/c^4) T^{\mu \nu}.
\]

(31)

where \( G \) is the Newton gravitational constant, \( c \) is the velocity of light and \( T^{\mu \nu} \) is the tensor of the energy and momentum of the physical system and \( R^{\mu \nu} \) is the Ricci tensor. Let us remark only, that while Einstein derived equations by the very sophisticated operations involving also the so called fictitious experiments with elevator, David Hilbert derived these equations easily and elegantly from the variational principle postulating only the appropriate Lagrangian and proved that general theory of relativity is only one of the problems of the Lagrangian mechanics. So, knowledge of mathematics is one of the most practical thing in constructing physical equations.

The fundamental objections to the Einstein approach is that the three-dimensional space cannot be curved in the three dimensional space and we have no evidence on the more than three-dimensional space. The objection is serious because the internal geometry on the sphere is possible only as the existence of the four-dimensional space in which the sphere is immersed. The resolution of this paradox is possible using the optical analogy. In optics there exist so called the optical length which is in no case equivalent to the geometrical length. In the nonhomogenous optical medium the distance of two bodies \( A \) and \( B \) is given by the optical length, or by the geometrical length which is always Euclidean. On the other hand in case of the space time with the gravitational field there exist, according to Einstein, only the physical length which can be measured only by light rays and clocks. Because the experimentalist is immersed in the Riemann space time, he has no possibility in this space-time to define the Euclidean length in contradiction to the optical situation.

Let us remark also that there many missing problems and missing solutions in general relativity. For instance, the solution of the mathematical pendulum, the Foucault pendulum, physical pendulum, free fall, the special relativistic limit of general relativity and so on. Some of these problems are discussed by Santilli (2005).

Now, the question arises, if the Einstein approach is the sole method how to describe gravity. Poincaré claims that the real objects are not described only by geometry \( G \), but by the geometry together with the physical law \( P \), or by \( G + P \). As the geometry is created by the a’ priori way, the physical law must be added to such a’ priory geometry in order to get the appropriate description of reality.

This alternative way was realized for instance by Gupta (1952), Feynman (1963) and Schwinger (1976) who has replaced the Einstein theory by the quantum field theory of gravitation where gravity is described by the tensor of massless field of the second rank which corresponds to the bosons with zero mass, having the spin 2 and helicity \( \pm 2 \). Attractive forces between bodies and all other effects are in this theory caused just by these bosons.

The basic formula in the source theory is the vacuum-to-vacuum amplitude (Schwinger, 1976):

\[
\langle 0_+ | 0_- \rangle = e^{\frac{i}{\hbar} W(S)},
\]

(32)
where the minus and plus tags on the vacuum symbol are causal labels, referring to any
time before and after space-time region where sources are manipulated. The exponential
form is introduced with regard to the existence of the physically independent experimental
arrangements which has a simple consequence that the associated probability amplitudes
multiply and corresponding $W$ expressions add. (Schwinger, 1976).

In the flat space-time the field of gravitons is described by the amplitude (32) with
the action ($c = 1$):

$$W(T) = 4\pi G \int (dx)(dx') \left[ T^\mu\nu(x)D_+(x - x')T^\mu\nu(x') - \frac{1}{2} T(x)D_+(x - x')T(x') \right], \quad (33)$$

where the dimensionality of $W(T)$ is the same as the dimensionality of the Planck constant $\hbar$. $T^\mu\nu$ is the tensor of momentum and energy, and for particle moving along the trajectory $x = x(t)$ it is defined by the equation

$$T^\mu\nu(x) = \frac{p^\mu p^\nu}{E} \delta(x - x(t)), \quad (34)$$

where $p^\mu$ is the relativistic four-momentum of a particle with a rest mass $m$.

The last formulas was used to determine the production of gravitons by the binary
system (Pardy, 1983b, 1994d). The method of calculation of the emission of gravitons is
an analogue of the method of calculation of the photon emission by the binary system
(Pardy, 2000a, 2000b, 2001c, 2002b, 2004d).

The special synthesis of the curvature approach and the spin 2 approach enabled
to determine the so called gravitational Čerenkov radiation which is analogous to the
Čerenkov radiation in a dielectric medium (Pardy, 1983a, 1983c, 1989a). Calculation
was applied with radiative corrections (Pardy, 1984; 1994c, 1994e) to zero temperature
and finite temperature situation (Pardy, 1994b, 1995). This effect was still not observed
similarly as the Hawking effect. While the electrodynamical Čerenkov effect with massive
photons was calculated (Pardy, 2002a) together with radiative corrections, it is not
excluded that the gravitational Čerenkov effect with massive gravitons is of the physical
meaning. The solution of this problem was still not published. The gravitons can be
evidently produced by plasma fluctuations. This problem was not solved by author. The
first step was performed in the case of photons generated by the plasma fluctuations
(Pardy, 1994f).

Gravity as every physical theory is dependent on crucial experiments. For instance,
on the deflection of light. It was confirmed by experiment. However if photon is massive,
or if it is considered as a quantum particle, then it is necessary to make new analysis
(Pardy, 2001a, 2005a).

We can say that in case of the general relativity the understanding of it is elementary
if we accept the Hilbert variational approach and the curved space-time as physically
meaningful. The existence of the massive gravity is possible from the postulation of the
massive gravitons. The existence of the massive classical gravity is open question and it
is open problem in the definition of the massive classical gravitational field.

While the Pythagoras theorem $c^2 = a^2 + b^2$ is valid for the right angle triangle in the
Euclidean geometry, it is not valid on the spherical surface and on the general Riemann
surface. Similarly the plane geometry Heron formula

$$P = \frac{1}{2} \sqrt{s(s-a)(s-b)(s-c)}; \quad s = \frac{1}{2}(a + b + c) \quad (35)$$
is not valid on the spherical surface. It means that spherical geometry, or Riemann geometry is substantially different with regard to flat geometry. It also means that Einstein theory of Riemann space-time substantially differs from the flat space-time geometry. The experiment must decide if the Einstein theory is more fundamental than the Schwinger source theory of gravity.

It is surprising that in the Newton period Pierre Gassendi developed the so called string model of gravity which states that between body A and B there is a string which transmits the attractive force. It seems that Faraday used the Gassendi ideas in his theory of electromagnetism. The string model of gravity is now considered as the problem of mathematical physics and it is not excluded that theory of this model will give fresh ideas in the string theory of matter (Pardy, 1996a; 2005b).

Definition of the space-time element and the Einstein equation with the cosmological constant makes it possible to define also the cosmological dislocations (Pardy, 2005a) and antidislocations. The definition of these dislocation in the flat space-time quantum gravity is open problem. There is no experimental confirmation of such dislocations till present time. Dislocations and antidislocations can annihilate to form light bursts in universe (Pardy, 2005a).

While Einstein used the fictitious experiment with accelerated elevator, there is a different approach to description of accelerated systems. The nonrelativistic approach by Pardy (2004a), and the relativistic discussion by Friedman and Gofman (2005).

In the nonrelativistic approach, the two systems $S(0, x, y, z)$ and $S'(0, x', y', z')$ are considered, where system $S'$ moves in such a way that $x$-axes converge, while $y$ and $z$-axes run parallel and at time $t = t' = 0$ for the beginning of the systems $O$ and $O'$ it is $O ≡ O'$ (Pardy, 2004a).

Let us suppose that system $S'$ moves relative to some basic system $B$ with acceleration $a/2$ and system $S''$ moves relative to system $B$ with acceleration $-a/2$. It means that both systems moves in the opposite direction one another with acceleration $a$ and they are equivalent because in every system it is possibly to observe the unit force caused by the acceleration $a/2$. In other words no system is inertial.

Now, let us consider the formal transformation equations between two systems. At this moment we give to this transform only formal meaning because at this time, the physical meaning of such transformation is not known. On the other hand, the consequences of the transformation will be shown very interesting.

We write the transformation equations in the form (Pardy, 2004a):

$$x' = a_1 x + a_2 t^2, \quad y' = y, \quad z' = z, \quad t' = \sqrt{b_1 x + b_2 t^2},$$

where constants involved in the equations will be determined from the viewpoint of kinematics. Since from the viewpoint of kinematics, both systems are equivalent, for the inverse transformation to the transformation (36) it must hold:

$$x = a_1 x' - a_2 t'^2, \quad y' = y, \quad z' = z, \quad t = \sqrt{-b_1 x' + b_2 t'^2}.$$  

The minus sign with coefficients $a_2$ and $b_1$ appearing for the reason that constant $a_2$ has the rate of acceleration while constant $b_1$ the rate of inverse value of acceleration.

Similarly, as in inertial systems, the hypothetical requirement can be now expressed that the transformation equations for system moving relative to themselves with acceleration include a suitable invariant function. Let us now define such transformations as follows:
\[ x = \frac{1}{2} \alpha t^2; \quad x' = \frac{1}{2} \alpha t'^2, \quad (38) \]

where \( \alpha \) is the constant having the rate of acceleration.

If we now substitute (37) into (36), we obtain from [\( x' = (1/2) \alpha t'^2 \) \( \iff \) \( x = (1/2) \alpha t^2 \)]

\[ x' = \Gamma(a)(x - \frac{1}{2} \alpha t^2), \quad t'^2 = \Gamma(a) \left( t^2 - \frac{2a}{\alpha^2} x \right); \quad \Gamma(a) = \frac{1}{\sqrt{1 - \frac{a^2}{\alpha^2}}} \quad (39) \]

and \( y' = y, \quad z' = z \).

Let us remark that the more simple derivation of the last transformation can be obtained if we perform in the Lorentz transformation the elementary change of variables as follows: \( t \to t^2, \quad t' \to t'^2, \quad v \to \frac{1}{2}a, \quad c \to \frac{1}{2} \alpha \).

The physical interpretation of this nonlinear transformations is the same as in the case of the Lorentz transformation only the physical interpretation of the invariant function \( x = (1/2) \alpha t^2 \) is open. The time transformation requires the correct interpretation of time. We use the time delay here as in the Fok book, where Fok writes that time delay is the form of the measurement procedure (Fok, 1961). It was proved that Fok interpretation of time is correct (Pardy, 1969). Some relativists suggest different interpretation of time dilatation.

Similarly, we can consider the length contraction in special theory of relativity (STR). The magnitude of the moving length depends on the measurement procedure. Let us prove it. The rod velocity \( v \) does not depend on the light velocity. Then, if the end points of rod are \( A \) and \( B \), and, if we define the point of observation \( O \) in \( S \), and, if the points \( A \) and \( B \) are identical with point \( O \) at time \( t_A, t_B \), then the length of the moving rod is evidently \( L = v(|t_A - t_B|) \). This definition of length as dual to the contracted length in STR and it is missing definition in STR. The measurement of the length by the Čerenkov effect was published recently (Pardy, 1997a).

If we want to measure the laser pulse, then it is necessary to use the more sophisticated approach. The duration of the laser pulse \( \Delta t \) of the rest laser in the system \( S \) follows from the relation \( c\Delta t = n\lambda \) where \( \lambda \) is the wave length of the laser light and \( n \) is the number of waves. Observer in the system \( S' \) which moves at the velocity \( v \) with regard to the laser system \( S \) writes \( c(\Delta t)' = n\lambda' \) where \( \lambda' \) is transformed wave length according to special relativity theory. Or,

\[ \lambda' = \lambda \sqrt{\frac{1 - v/c}{1 + v/c}} \quad (40) \]

for the observer moving toward the laser pulse. This relation, known as the relativistic Doppler formula can be used as a test of special theory of relativity to show that the one-way velocity of light is \( c \). The nonrelativistic relation is \( \lambda' = \lambda(1 - v/c) \) and the nonrelativistic \( (\Delta t)' \) differs from the relativistic \( (\Delta t) \).

We know from the history of physics, that Lorentz transformation was taken first as physically meaningless by Lorentz himself and later only Einstein decided to put the physical meaning to this transformation and to the invariant function \( x = ct \).

The transformation (39) forms one-parametric group with parameter \( a \). To prove it we must prove by the direct calculations the four requirements involving in the definition of a group. However, we know, that using relations \( t \to t^2, \quad t' \to t'^2, \quad v \to \frac{1}{2}a, \quad c \to \frac{1}{2} \alpha \), the nonlinear transformation is expressed as the Lorentz transformation forming the one-parametric group. And this is a proof. Such proof is equivalent to the proof by direct
calculation. The integral part of the group properties is the so called addition theorem for acceleration.

\[ w_3 = \frac{w_1 + w_2}{1 + \frac{w_1 w_2}{\alpha^2}} \]  

(41)

where \( w_1 \) is the acceleration of the \( S' \) with regard to the system \( S \), \( w_2 \) is the acceleration of the system \( S'' \) with regard to the system \( S' \) and \( w_3 \) is the acceleration of the system \( S'' \) with regard to the system \( S \).

The relation (41), expresses the law of acceleration addition theorem on the understanding that the events are marked according to the relation (39). In this formula as well as in the transformation equation (39) appears constant \( \alpha \) which cannot be calculated from the theoretical considerations, or, from the theory. What is its magnitude and whether there exists such a physical field that is consistent with the designation of the events given by the relations (39) can be established only by experiments. On the other hand the constant \( \alpha \) has physical meaning of the maximal acceleration and its meaning is similar to the maximal velocity \( c \) in special relativity.

It is not excluded that the maximal acceleration constant determines the upper limit of the Higgs boson and links the mass of \( W \) boson with the mass of the Higgs boson. The LHC and HERA experiments will give the answer to this problem. At the same time it is not excluded that the maximal acceleration constant is related to the so called Hagedorn temperature which is the phase boundary temperature between the hadron gas phase and the deconfinement state of mobile quarks and gluons. In other words, acceleration of quarks and gluons in the hadron gas is restricted by the maximal acceleration.

We can also suppose in analogy with the special relativity that mass depends on the acceleration for small velocities, in the similar way as it depends on velocity in case of uniform motion. Of course such assumption must be experimentally verified and in no case it follows from special theory of relativity, or, general theory of relativity. So, we postulate ad hoc, in analogy with special theory of relativity:

\[ m(a) = \frac{m}{\sqrt{1 - \frac{a}{\alpha^2}}}, \quad v \ll c, \quad a = \frac{dv}{dt}. \]

(42)

Let us derive as an example the law of motion when the constant force \( F \) acts on the body with the rest mass \( m \). Then, the Newton law reads [15]:

\[ F = \frac{dp}{dt} = m \frac{d}{dt} \sqrt{\frac{v}{1 - \frac{a^2}{\alpha^2}}}. \]

(43)

The solution of this equation was found (Pardy, 2003b, 2004a). For \( F \to \infty \), we get \( v = \alpha^2 t \). This relation can play substantial role at the beginning of the Big Bang, where the accelerating forces can be considered as infinite, however the law of acceleration has finite nonsingular form.

We know that the dependence of the mass on acceleration follows from quantum electrodynamics (Ritus, 1979). Our case is based on the different approach. In case that the constant "maximal acceleration" will be confirmed for instance by LHC, then, the high energy physical theories, gravitation and cosmology must be modified, including the Hawking effect. Evidently, this constant will generate revolution in cosmology.


5.2 Understanding of quantum mechanics

Although the mathematical structure of quantum mechanics is elementary, or, in other words, this theory is only Schrödinger equation applied to many physical situation, the most difficult problem is the derivation of the Schrödinger equation and the origin of probability behavior of an electron. Till present time, the problem was not solved.

To solve this problem, Feynman invented so called path integral approach to quantum mechanics with the goal to remove the mystery of quantum mechanics. The substance of the Feynman path integral is, that the wave function of an electron, is the sum amplitudes taken over all classical trajectories of a particle (Blokhintzev, 1971; Pardy, 1973c). The interpretation of the Feynman sum is such, that electron moves from point A to B along all classical trajectories connecting A and B (Pardy, 1973c).

According to Feynman, the total probability amplitude $U(A, B)$ from a particle transition from point A to point B is as follows

$$U(A, B) = \frac{1}{C} \sum_{\text{over all trajectories from A to B}} e^{i\frac{\hbar}{\hbar}S[x(t)]},$$

(44)

where $S$ is the classical Hamilton-Jacobi action function

$$S = \int_{t_A}^{t_B} L[\dot{x}(t); x(t)]dt,$$

(45)

where $L$ is Lagrange function.

We can see that all amplitudes $\exp\{i/\hbar S\}$ are multiplied only by a constant $1/C$. In case that the electron is in some stochastic medium, for instance inside the black-body where the thermal stochastic photons are present the sum must be modified by some weight function. We take the Wiener measure of the Brownian motion for the weight function of a particle in a stochastic medium (Pardy, 1973c). In other words, the original trajectories are modified. If the result gives the physical meaningful consequences, then also the modification of trajectories is physically meaningful. It was shown that the result of such generalization is the change of mass of electron according to the formula (Pardy, 1973c):

$$m \rightarrow m + i\delta,$$

(46)

where $\delta$ is related to the so called diffusion constant of the Brownian motion. The complex mass of electron means that no energetic level is stationary, which is very natural when electron is moving in the stochastic medium. However, if the space as such is not euclidean but stochastic, or, infinitesimally deformed, for instance in the vicinity of the thermal Big Bang, then it seems that the modification of the trajectories is mathematically necessary. Hawking (1989) accepted the Feynman theory over the path with the interpretation that electron moves from A to B by every possible path. The possible modification of the Feynman integral by some additional properties of space time is not involved in the Hawking monograph. Similarly, such approach to the Feynman integrals was not elaborated in the literature.

On the other hand the complex mass of electron naturally appears in the quantum electrodynamical description of the synchrotron radiation and it is possible from it to calculate the spectrum of the synchrotron radiation. The nonstability by the complex mass, of the orbit of electron in synchrotron was discussed (Pardy, 1985).
There is one specific case where Feynman sum is restricted to one trajectory. This is so-called Volkov solution of the Dirac equation. The solution is of the form (Berestezkii, 1989; Pardy, 2003a, 2004b, 2004c):

$$
\psi_p = R \frac{u}{\sqrt{2p_0}} e^{iS} = \left[ 1 + \frac{e}{2kp} (\gamma k)(\gamma A) \right] \frac{u}{\sqrt{2p_0}} e^{iS},
$$

(47)

where $u$ is an electron bispinor of the corresponding Dirac equation

$$(\gamma p - m)u = 0,
$$

(48)

with the normalization condition $\bar{u}u = 2m$.

The mathematical object $S$ is the classical Hamilton-Jacobi function, which was determined in the form:

$$
S = -px - \int_0^{kx} \frac{e}{(kp)} \left[ (pA) - \frac{e}{2} (A)^2 \right] d\varphi
$$

(49)

and $A(\varphi)$ is a periodic potential with $\varphi = kx$. For the electron motion in the two potentials $A(\varphi)$ and $B(\chi)$, and for the specific configuration of fields $A, B$ (Pardy, 2004c), we get

$$
\psi = R(\varphi) R(\chi) \frac{u}{\sqrt{2p_0}} e^{iS(\varphi)} e^{iS(\chi)}.
$$

(50)

The Volkov wave function is quantum mechanical one and it involves classical action, however no integral over trajectories is present and at the same time this is not the WKB approximation. It means that all trajectories are mutually canceled excepting the classical one. Why? This is an open and the missing problem in the monographs on Feynman integral.

6 The selection of facts

It is well known that the explosive development of industry was initiated in the beginning by the absolutely nonpractical ideas (The Maxwell equations, the Hertz experiments with the electromagnetic waves, the special theory of relativity, the Boole algebra and the mathematical logic and so on). Some of the initiators of such unpractical ideas were unpractical people who died poor and who never thought of the practical employment of their ideas. Nevertheless, they had a guide that was not their own caprice. It was the happiness for society that such ideas were not refused. Of course, some ideas are always rejected and the question arises what are the mathematical and physical ideas which influence the life of the industrial society by the maximal way.

According to Poincaré (1913), the most important facts are those which can be used several times, or which have a chance to recurring. However, what are the facts of such properties? According to Poincaré (1913), the simple facts. Because it is evident that a complex fact is composed from many simple facts by chance and that only a still more probable chance could ever so unite them again, on the contrary to the case of a simple fact.

The question is what is the simple fact. The astronomer has found the simple fact a point which replaces the universe bodies, because the distance between the stars are
immense, that each of the universe body appears only as a point and qualitative differences disappear and because a point is a simpler object than a body with shape and qualities.

Particle physicists has found that the simple facts in the microworld are quarks which are point-like, massive and charged together with electrons, positrons, \( \mu \)-mesons, \( \tau \)-mesons and neutrinos which are also (approximately) point-like with regard to the present experimental knowledge. All matter is composed from these particles and from intermediate bosons which cause the electromagnetic, weak, strong and gravitational interactions between particles and bodies.

The similar situation is in biology, chemistry and so on, where it is possible to establish the simple facts.

The fundamental rule to perform a good selection of facts is not ascertain resemblances and differences of the mathematical objects, however, to discover similarities hidden under apparent discrepancies. This is what gives value to certain facts that come to complete a whole and shows that it is the faithful image of other known wholes. Mathematicians and physicists do not select facts randomly. They try to condensate a great deal of experience and great deal of thought into a small volume and that is why a little book on mathematics and theoretical physics contains so many pieces of knowledge.

According to Poincaré (1913), the selection of basic facts and searching for these facts is accompanied by the specific mathematical emotions which can be called as the emotion of the mathematical beauty. These emotions for the motivation for study of mathematics and theoretical physics. Poincaré (Poincaré, 1913; Wolpert, 1993) writes:

”The scientist does not study nature because it is useful; he studies it because he delights in it, and because it is beautiful. Of course, I do not speak here of that beauty which strike the senses, the beauty of qualities and appearance; not that I undervalue such beauty, far from it but it has nothing to do with science. I mean the profound beauty which comes from the harmonious order of the parts and which a pure intelligence can grasp.”

Or,

”If nature were not beautiful, it would not be worth knowing and life would not be worth living”.

The mathematical beauty is not the beauty which strikes senses, the beauty of qualities and appearance. This is (Poincaré, 1913)

“intimate beauty which comes from the harmonious order of its parts, and which a pure intelligence can grasp” (Poincaré, 1913).

Or, (Poincaré, 1913)

“... the care for the beautiful leads us to the same selection as care for the useful. Similarly, economy of thought, that economy of effort, which according to Mach, is the constant tendency of science, is a source of beauty as well as a practical advantage”.

22
The question arises, whether the mathematical beauty is the sufficient condition for the theory to be physically true. It is necessary to say that it is possible to invent many mathematical theories, equations, relations and so on which have mathematical beauty but which do not correspond to nature.

We known that the basic fact of Newton physics is the notion of force. **Every force is invisible**, including Lorentz force and forces in particle physics. They transform according to the transformation laws of the special theory of relativity. The basic theoretical object in the Lagrange mechanics is the Lagrange function \( L = T - V \), where \( T \) is the kinetic energy of a particle and \( V \) is the potential energy. Potential energy was introduced by Rankine – the missing information in textbooks. Force in Lagrange mechanics is defined from potential. Schrödinger equation involve potential and not force. Similarly the general relativity by Einstein does not work with force. Force in quantum field theory is derived from the interactions. Potential energy is derived from the Green function of a particle. While force and potential are basic ingredients in classical mechanics, in quantum field theory not. We use here the propagator, or the Green function.

The propagator, or the Green function, for the massive photon in dielectric medium with index of refraction \( n \) was derived as (Pardy, 2002a)

\[
D_+(x - x', m^2) = \frac{i}{c} \frac{1}{4\pi^2} \int_0^\infty d\omega \sin\left[\frac{n^2 \omega^2}{c^2} - \frac{m^2 r^2}{h^2}\right]^{1/2} |x - x'| \frac{e^{-i\omega|t - t'|}}{|x - x'|}. \tag{51}
\]

The potential is according to Schwinger defined by the formula:

\[
V(x - x') = \int_{-\infty}^\infty d\tau D_+(x - x', \tau). \tag{52}
\]

The \( \tau \)-integral can be evaluated, in case of the massless photon, using the mathematical formula

\[
\int_{-\infty}^\infty d\tau e^{-i\omega|\tau|} = \frac{2}{i\omega}. \tag{53}
\]

and the \( \omega \)-integral can be evaluated using the formula

\[
\int_0^\infty \frac{\sin ax}{x} dx = \frac{\pi}{2}, \quad \text{for} \quad a > 0. \tag{54}
\]

After using eqs. (53) and (54), we get

\[
V(x - x') = \frac{1}{c} \frac{1}{4\pi} \frac{1}{|x - x'|}. \tag{55}
\]

In case of the massive photon, the mathematical determination of potential is the analogical to the massless situation only with the difference we use the propagator (51) and the table integral:

\[
\int_0^\infty \frac{dx}{x} \sin \left( p\sqrt{x^2 - u^2} \right) = \frac{\pi}{2} e^{-pu}. \tag{56}
\]

Using this integral we get that the potential generated by the massive photons is

\[
V(x - x', m^2) = \frac{1}{c} \frac{1}{4\pi} \exp\left\{ \frac{-m c n}{h} |x - x'| \right\} \frac{1}{|x - x'|}. \tag{57}
\]
So we have seen that the basic fact in quantum field theory was the Green function, then potential and then force derived from the potential. The question arises what is the potential between two charges immersed into the sea of photons of the black body. This problem was solved (Pardy, 1994g).

7 The scientific activity

The fundamental mechanism of the scientific research was defined by Gilman (1985):

"Research work is inherently sequential. It involves overcoming a series of obstacles that must be approached one after one. This cannot be avoided because a subsequent obstacle does not become well-defined until the preceding one has been overcome. Thus, unlike manufacturing, research work does not lend itself to being accelerated by doing several operations in parallel. And the rate at which it achieves progress depends on the instantaneous effort that is put into it”.

Similarly to the Gilman philosophy expresses the physical credo David Stern (Stern, 1993). According to him, scientific work requires continuously to keep notes of scientific ideas, collect them, transcribe them, illustrate them, to use word processors in order to edit and produce them.

In order to realize the progress in science it is necessary to select the right text for study. A poor text is frustrating, only a good one makes soar. It is necessary to select text which provides intuitive insights. And the best way to obtain insight is to solve problems which follows directly from the text or are invented independently on it. The problems must be physically meaningful. Only such problems are interesting. It is necessary to solve big problems because no one care about publishable petty results. There is no need to have fear from the big problems because every problem can be divided or splitted into a sum of small problems easily solvable. However, what is big and good problem? It obviously depends on the scientific educations which enables to formulate the big problems from the big theoretical experience. It depend also on the mentality of a person who estimates the problem and also on the situation in the scientific world. The best way is to have not only one problem but to formulate many problems. Then, to establish the hierarchy of them in order to decide what problem is solvable immediately and what problem is more difficult for solution.

There is no need to have a fear from drudgery because no pain, no gain. On the other hand a minute thinking is more effective than hours of memorising.

The effective way is discussion on the similar problems with experts. At the same time the effective way is to write a review of what was yet done in the certain field and it forces us to think not only analytically but also synthetically. It is obvious that it is possible to unify all heuristical activities in the maximalistic form of the scientific publication. Namely, to write article with the goal to give clear new mathematical formulation of the new or old interesting problem, to find solution and to show that the result is principally experimentally possible to verify. Only in this situation one has the very strong motivation for dealing with science. Such approach leads to discoveries in case we use the correct heuristics. However, the integral part of every heuristics is knowledge of the process of problem solving. Let us look on this problem.
8 Problem solving

We know from the history of mathematics that Newton approach to the problem solving was expressed by the words:

"I continuously keep in the mind the subject of my investigation and with patience I wait, unless the first flash little by little turns out into the dazzling light".

The deeply true rule for the very effective problem solving and making the mathematical discoveries was expressed by Poincaré (1913) in the following form:

"The mathematical discovery, the great or the little one, never arises spontaneously. They ever suppose a ground into which are pieces of knowledge sewn and very well cultivated by work, conscious or unconscious".

The substance of the problem solving is also the right question because if we answer the incorrect question, we move in the blind street. Solution is the long part of human activity. Solution of problems is a sequence of orderly steps. However, the human cognitive actions that arrive at the solutions do not form at the first moments of such sequence. The sequence is the final result of the human cognitive process of the problem solving. The most of the elementary actions in the problem solving which do not form the final chain may consists of false starts, daydreams, idiosyncratic associations or images. Only person well trained in the solving of the particular problems has the experience for the construction of the final chain from which the start is going to the correct result.

The solution of the problem comes after proper analysis of the situation and after application of the method "trial and error". This method is in inevitable integral part of the problem solving. Nevertheless, solutions are generally sudden integration. Usually the significants of the problem situation come together and are integrated in a unique way in one pulse of rapid attentional integration. This characteristic suddenness is usually called as insight. But for this to happen (Blumenthal, 1977),

"attention must be free enough to go well beyond the raw data from view due to overloading of the cognitive capacities”.

If we speak about the free attention we mean practically automatical formation of of sequences during the problem solving. Automatization of the mental processes is the fundamental basis for the growth of the development of the human knowledge. With the automatisation of the cognitive processes, which means operations without detailed attentional focusing, attention is free to concentrate on the goals rather than on the means of performance. The original system of attentional activity then become automatic tools in the construction of the more complex mental formation. Or, (Blumenthal, 1977),

"Our ability to learn may be thus limited to the degree that our attention is free and to the degree that it can be directed to the events to be learned”.
While on the other hand the well-developed automaticity may at times block creativity or blind the person to solving the problem, on the other hand without automaticity there is no progress. The creative person must be able to de-automatize and also to apply old automatism in the new context. According to Whitehead (1928)

"Civilization advances to the degree that we can perform important processes without thinking about them”.

The last statement is the idea of the computer creativity. We work with programs of the computer abstraction, conversation, proofs of theorems, compilation of texts and so on. At present time there are computer chess players and computer players of the different kinds of plays. We have intelligent programs such as MATHEMATICA, MAPLE, MATLAB and other superprograms which are able to solve partial problems of mathematics. Every computer program is only well organized system of operations in the microprocessor machine. Of course, we believe that in future the organization of operations will be so brilliant that computer will be able solve not only all problems from QED, QCD, gravity, cosmology, topology and so on, but also, with some additional communication with scientists, to create all physical theories and write the scientific articles and monographs of high quality.

There is no problem for computer to define the imaginary number \( i \) as the solution of the elementary equation \( x^2 + 1 = 0 \), and there is no problem for computer to prove the famous Euler formula

\[
i^i = e^{-\frac{\pi}{2}} \tag{58}
\]

and other famous Euler formulas. There is no problem for computer to prove \( \sqrt{2} \neq p/q \) where \( p \) and \( q \) are the integers. On the other hand, to prove that \( \sqrt{2} = P/Q \) for the infinite integers \( P \) and \( Q \) is for computer impossible. The problem is infinity. Infinity and the infinitesimal is the deadline of every computer.

9 General conditions for creativity

Now, let us investigate the necessary general factors from which the creative process involving problem solving is built up. The complete act of the creative production consists of the four stages: Preparation, Incubation, Illumination, Verification.

Other schemes of the creative work was elaborated by Rossman (Guilford, 1963) who, after study of the 700 productive inventors concluded that the substantial stages consist in the seven steps. Observation and need of solution of difficulty, analysis of the need, survey of all available information, formulation of objective solutions, critical analysis of the solutions, the birth of the new innovation - the idea proper, experimentation to test the idea.

John Dewey gives the following rules for the problem solving (Guilford, 1963). Recognition of a problem, analysis of a problem, suggestion of possible solutions, testing of the consequences, judgment of the selected solution. So, the similarity between the schemes of different authors are obvious.
10 Theoretical physics and technology

What is the relation between technology and theoretical physics? Let us remember quotation of Francis Bacon from his Novum Organon (Rescher, 1978):

”Neither the naked hand nor the intellect left to itself can effect much. It is by instruments and helps that work is accomplished, which are as much needed by the intellect as by hand. And as the instruments of the hand either impel or guide its motion, so the instruments of the mind either encourage or admonish the intellect.”

So, technology forms the inspiration necessary for the theoretical thinking. Pure technology leads to empirism and alchemy and pure theory leads to useless symbolic meditation.

Technology is very much older than science. Unaided by science, technology gave rise to the crafts of primitive man, such as agriculture and metalworking, the Chinese triumphs of engineering, renaissance cathedrals, and even the steam engine. Not until the nineteenth century did science have an impact on technology. In human evolution the ability to make tools, and so control the environment, was a great advantage, but the ability to do science was almost entirely irrelevant.

The history of science teaches us that there exist an escalation of price of the innovation of science. But why? Why should the resource-cost of significant scientific discoveries increase so substantially with the progress of science? Is this trend only the short-term phenomena or the structural facts deep-rooted in the nature of science? What is the explanation of the cost-escalation and the logarithmic retardation of the production of scientific results in the modern science? What is the explanation of the cost-escalation of LHC? Planck’s principle is hypothesis that the resource-input costs are proportional to the scientific innovation. The reasons for the deceleration of science are speculative, nevertheless there are facts for such development.

A certain amount of mathematical detail is unavoidable in testing the model which explains the relationship between science and technology. It is necessary to have some explicit deployment of certain basic assumptions about the nature of scientific work. Unless they are set out with reasonable precision, there is no way of testing the compatibility and consonance of these assumptions.

Technology is obviously the applied science, and the technology is crucially dependent upon previous technology (Recher, 1978). For instance the experimental physics heavily depends on some very advanced technology. Currently, in fields such as plasma physics and thermonuclear research, there are many theoretical physicists, with a broad range of interest and expertise, some with a background in elementary particle physics, intimately concerned with engineering questions.

It is non exaggeration to say that the laboratory science is the result of the industrial revolution, or the fruit of its technological harvest.

Just as scientific knowledge and methods are entering technology, scientific research is in turn determined by technology. Technology provides instruments and apparatus for scientific investigation and technological development throws up new fundamental problems that stimulate the course of scientific research. For instance the transuranic elements, many isotopes and elementary particles, and most organic compounds are only created at all through the use of technical aids.

Natural science is fundamentally empirical and its advance is critically dependent not on human ingenuity alone, but on the phenomena to which we can only acces through
interactions with nature. The dependence of the theoretical advance on the goading of the experimental results was brilliantly expressed by Max Planck (Rescher, 1978):

“...it was the facts learned from experiments that shook and finally overthrew the classical theory. Each new idea and each new step were suggested to investigators – where it was not actually thrust upon them – as the result of measurement”.

The fundamental research in physics is crucially dependent on the progress of technology. Historical examples are overwhelmingly numerous. Superconducting magnets for a giant bubble chamber are available only because of the extremal industrial effort that followed the discovery of hard superconductors. In experimental physics, high-energy physics and astronomy – wherever photons are counted, which includes much of fundamental physics – photomultiplier technology has often paced experimental progress. The multidirectional impact of semiconductor technology on experimental physics is obvious. In several branches of fundamental physics it extends from the particle detector through nanosecond circuitry to the computer output of analyzed data.

The creative scientist must be sensitive for specific situations and he must be able to put the crucial questions. However, on the other hand he must have a well-developed sense of the possible as to the issues which, in the existing state of research technology, one can hope to tackle effectively with the instruments in hand.

Let us discuss the dependence of the development of the particle physics on the specific technology which enables such development. The knowledge of the structure of atomic nuclei and of elementary particles has been derived mainly from the study of reactions between colliding particles. The method used is to bombard a "target" with a stream of particles and study the particles resulting from this interaction. The simplest type of the reaction is the elastic scattering in which colliding particles simply deflect each other without undergoing any other change. In this case the most close distance of approach which can be explored depends on the initial energy. In inelastic reactions, on the other hand, one or both of the colliding particles may undergo changes and in addition new particles and quanta of the electromagnetic radiation may be created. The creation of new particles and quanta can occur only if the necessary energy is available in the kinetic energy of the colliding particles. Consequently, the kinetic energy is the determining factor for the phenomena to be observed. The high energy particles occur in nature or as a result of interaction of particles accelerated in accelerator. Such accelerators have already made available particles with energy exceeding $2.5 \times 10^{10}$ eV. Particles in a higher range of energies are accessible only through experiments with LHC and cosmic rays.

This dependence of high-energy physics on technology and engineering frequently stretches the capabilities of existing technology to the utmost, requiring innovations and extrapolations that go well beyond any present state of the art. Because the resulting technological developments have implications much broader than their use in the particle physics, all technology benefits from the opportunity to respond to this pressure. New technological developments occur sooner than they would in the absence of such pressure, and they often present new engineering opportunities, that can be exploited immediately. Let us recall some examples: very high vacuum systems, sources of enormous radio frequency power, cryogenic systems, large-scale static superconducting magnets, pattern recognition devices, very fast electronic circuits, computers and so on. In this sense, elementary particle physics has had a major impact on technology, but the effect was not the result of the direct research.
The development of special relativity was evidently conditioned by the technological success of Michelson and Morley who by their famous interferometer proved the nonexistence of the aether wind. Without such technological success, the development of the special relativity was improbable.

All other experiments which confirmed the relevance of the special relativity theory, such as the dilation of time, the famous Einstein relation between mass and energy, the mass dependence on velocity and so on, was evidently enabled by the high technology and its use in the experimental physics.

Similarly in the general relativity and gravitation the confirmation of the gravitational waves was conditioned by the gigantic radiotelescope which is also the success of high technology. The experimental proof was given by Taylor and Hulse at the Arecibo radiotelescope. They performed the systematic measurement of the motion of the binary with the pulsar PSR 1913+16 (Damour et al. 1992; Taylor et al. 1992; Taylor, 1993). They found that the generalized energy-loss formula, which follows from the Einstein general theory of relativity, is in accordance with their measurement. This success was conditioned by the fact that the binary emits sufficient gravitational radiation to influence the orbital motion of it at the observable scale. PSR 1913+16 is now considered as the best general relativistic laboratory.

It is evident that without symbiosis of extremal high technological equipment which participated in measurement it was not possible to find that all data obtained by measurement are compatible with the Einstein quadrupole formula.

11 New phenomena and technology

The really major advances in natural science involve the opening up of a new point of view or in other words the new way of posing old problems.

One of the key governing conceptions of the contemporary work in science is the idea of ”new phenomena” which falls upon the scientific community of the day like a bolt from the blue. This idea is handily developed in a passage by the eminent Russian physicist Piotr Kapitza (Kapitza, 1964).

“I would like to define a ”new phenomenon” as a natural phenomenon that can neither be foreseen nor explained on the basis of existing theoretical concepts. To clarify the definition, I will name those new phenomena which, in my opinion, were discovered in the past 150 years. The first discovery I would like mention is the discovery of the Galvani electric current in 1789. This discovery in no way flowed from the theoretical conceptions of that period. (Volta only half finished this discovery, if you like). Another discovery worthy of note, in my opinion, was Oersted discovery in 1820 of the influence of electric current on a magnetic needle. I do not consider the Faraday discovery of electromagnetic induction as a new one, since it is nothing more, than the converse discovery to that made by Oersted, which it was already possible to foresee. The Oersted discovery led to Maxwell’s equations, and all others were but an elaboration of this discovery. To foresee the Oersted discovery theoretically was impossible.
A further example of a new phenomenon is the Hertz discovery of external photo-effect (not electromagnetic waves which we all know) which thirty or forty years later led to Einstein’s equations, which were impossible to foresee theoretically. The principles of indeterminacy and the quantum theory were contained in the discovery of the photo-effect; all the others were just a further elaboration.

Then, I would include the Becquerel discovery of radioactivity. This also was an unforeseeable phenomenon. On the other hand, the discovery of the electron cannot be counted as an independent discovery. Next, I would note the Michelson and Morley experiment, the result of which was impossible to foresee. Then Hertau’s discovery of cosmic rays, which was also unforeseeable. It also appears to me that the discovery of uranium fission by Lise Maitner and Otto Hahn should be noted”.

The new data can be derived only by the new technology and once this technology becomes available there results a land-office scramble for its exploitation. Nothing more clearly manifests the dependency of scientific progress upon advances in the technology of data-aquisition and coordination which create the conditions requisite for scientific innovations than the common phenomenon of a clustering of redundant findings. Science grows rapidly around laboratories, around discoveries which make the testing the hypotheses easier, which provide the sharp and consistent selective systems. Thus the barometer, microscope, telescope, galvanometer, cloud chamber chromatograph all have stimulated rapid scientific growth.

Nothing could more emphatically demonstrate the nonability of the mere intellect unaided by the technological means for the acquisition of empirical data than the fact that nowadays in many areas of natural science it is virtually impossible that major discoveries or any original work or real value and interest should come from some quarter outside the handful of major research groups or institutes that are "on top of the problem" at hand and are privy to the new data generated by the frontier technology of research that represents a special "in-house" information source such as particle accelerator, research reactors, radiotelescope and so on. The case of Einstein who was able to do discoveries without laboratories is necessary to discuss apart.

On the other hand the progress without the new data is, of course, possible in various fields of scholarship and research. The example of pure mathematics shows that the discoveries can be made in the area of inquiry that has no empirical datum content at all. But this is not the case which concerns directly the natural science. Only natural science depends directly on the empirical data and it differs from the so called pure sciences as mathematics, logic, or hermeneutics, where in case of hermeneutics the substance of the intellectual activity consists in the imaginative reinterpretation of the old data from the new conceptual perspectives. Without the influx of new empirical data all one could do is to proceed to an increasingly sophisticated conceptual resystematization and reinterpretation of the same data base. While this might indeed constitute a progress of sorts, it just is not the sort of progress at issue in natural science, and blocks the way to the empirical process of testing the hypothesis and elimination the indirect ideas on which the progress of science as it is well known standardly depends. The sort of reinterpretative innovation can only have major significance in the human sciences where the theleological concept of meaning is operative. The reinterpretation might count as "progress" but
this sort of progress will not represent a major advance in the area of natural science where the strictly hermeneutic issues of meaning and theology at best play a minor and peripheral part. Nevertheless the hermeneutics has the pedagogical values and can be a good gymnastics for the human brain.

12 Reciprocity

The scientific progress in technology depends undoubtedly on the progress of science and it may be easy to see that the progress in science depends on progress in technology. The relation between science and technology is in such a way reciprocal (Toulmin, 1972).

“A natural science and an associated technology are partners in a kind of historical gavotte, developing most effectively when their changes are harmoniously synchronized”.

The expressive explanation of the relationship between science and technology is presented by Hermann Bondi (1967). He writes:

“I have spoken earlier of disproof as the essential agent of progress, but why can we disprove today what we couldn’t disprove yesterday? The answer is that today we can carry out more accurate experiments relating to matters that were inaccessible yesterday. We can do so because of the progress of technology. And so a progressing technology is an absolutely essential condition for a progressing science. It is a peculiar disease of this country, I think to feel that science sort of marches in front and that poor, dirty technology follows a long way behind. But the relation of science and technology is the relation of the chicken and the egg; you cannot have the one without the other. It is true that modern technology derives from modern science, but we would not have any of modern science without modern technology”.

The historical development of science thus moves in a dialectic feedback of interchange from the one side to the other of the theoretical-technological divide, doing so at increasing levels of sophistication. It can be illustrated by construction of ITER where the compression of matter with laser beams will be probably used in order to get nuclear fusion (Nakai and Mima, 2004).

ITER means “the way” in Latin and it can be translated as International Thermonuclear Experimental Reactor. While the problem of interaction of an electron with two laser beams was solved only theoretically with Dirac equation in the restricted form (Pardy, 2005c), it leads to the practical use if we will consider more realistic situation with the laser pulses (Pardy, 2003a). The practical meaning is, that two laser beams (pulses) impinging on a target which is constituted from material in the form of a foam, can replace 100-200 laser beams impinging on a normal target and it means that the nuclear fusion with two laser beams is realistic in combination with the thermonuclear reactor to generate the physical process of implosion (Rozanov, 2004).

Nuclear fusion involves the bringing together of atomic nuclei. The sum of the individual masses of the nucleons is greater than the mass of the whole nucleus. This is because the strong nuclear force holds the nucleons together. Then, the combined
The nucleus is a lower energy state than the nucleons separately. The energy difference is released in the fusion process.

There are two major fusion processes. The magnetic confinement and inertial confinement. The inertial fusion occurs inside targeted fuel pellets by imploding them with laser or particle beam irradiation in brief pulses. It produces extremely high densities in the target where the laser pulse creates a shock wave in the pellet that intensified by its internal geometry. On the other hand, magnetic fusion devices, like the tokamak, operate at lower densities, but use magnetic fields to confine the plasma for longer time.

To achieve a burning plasma, a sufficiently high density of fuel must be heated to temperatures about 100 million degrees of Celsius that the nuclei collide often enough despite their natural repulsive forces and energy losses.

The fuels to be used are two isotopes of hydrogen. Namely, deuterium and tritium. While deuterium occurs naturally in sea water and it means it is inexhaustible, tritium can be bred in a fusion system when the light element, lithium, absorbs neutrons produced in the fusion reaction. World resources of lithium are inexhaustible and it means that also the energy obtained by fusion process is practically infinite. There are only a few fusion reaction channels in the D-T mixtures in ITER:

\[ D^2 + T^3 \rightarrow He^4(3.5\text{MeV}) + n(14.1\text{MeV}) \]  \hspace{1cm} (59)

\[ D^2 + D^2 \rightarrow He^3(0.8\text{MeV}) + n(2.5\text{MeV}) \]  \hspace{1cm} (60)

\[ D^2 + D^3 \rightarrow T^3(1.0\text{MeV}) + p(3.0\text{MeV}) \]  \hspace{1cm} (61)

\[ D^2 + He^3 \rightarrow He^4(3.7\text{MeV}) + p(14.7\text{MeV}) \]  \hspace{1cm} (62)

Fusion reaction only occur at a sufficient rate for useful power production when the nuclei have energies in the range 10 - 100 keV and can collide almost continuously.

The high temperature fusion is not the final word of the nuclear physics. The so called cold fusion is also considered as a source of the cheap energy and the development of this strategy is very perspective using the so called sonoluminescence. Sonoluminescence is generated by ultrasound which produces microscopical bubbles in a liquid. The temperature inside each bubble is tens thousands of Kelvin and it makes possible for some ingredients to generate the fusion.

The very modern approach to future energetics is to get the pure energy from the reaction of matter and antimatter. Antimatter can be created during some experiments in particle accelerators and then included in the special traps. Matter and antimatter forms the interaction called annihilation with the maximal product of energy. The so called annihilation reactor is the reactor without jeopardy.

All new approach to energetics laser fusion in ITER, cold fusion, annihilation reactor represent the reciprocity between theory and technology. It is evident that the byproducts of such reciprocity are many fundamental physical discoveries generated only by this way.

The reciprocity can be realized also by so called theoretical inventions, which are not still realized but they are described and suggested theoretically. Such invention is for instance the so called magnetronic laser MAL for the therapy of cancer. It is proposed in order to show the alternative way of the therapy of cancer (Pardy, 2003c).
The other possibility of the reciprocity between technology and theory is the so called laser acceleration of elementary particles. This is very old problem and QED approach was suggested (Pardy, 1997b, 2001b).

13 The technological limit

Progress in science is limited at any given stage of scientific history by the implicit barriers set by the available technology of data acquisition and processing. Technological dependency sets technological limits.

The crucial example is the situation in the ancient Greek. From the given information technology of the day it is not just improbable but actually inconceivable that the Greek astronomers should have come up with an explanation for the red shift or the Greek physicians with an account of the bacteriological transmission of some communicable disease. The reason for this is simple because the relevant types of data needed to put such phenomena within the cognitive grasp of man simply lay beyond their reach. Progress in theorizing in these directions was barred by a technological barrier on the side of data that was as absolute as the then-extant technological barriers in the way of developing the internal combustion engine or the wireless telegraph. So we endorsed the idea that the technology is crucially conditioned by the deliminative role of the technological possibilities of the time.

On the other hand modern technology crucially depends on the theoretical basis of science. The obvious example is the knowledge of the infinitesimal calculus. In time of Galileo and Descartes it was a custom to study the acceleration of a body and its dependence on the distance or time. Nevertheless, it was absolutely impossible to develop dynamics of the more complicated motions of bodies because the mathematical instruments of Galileo or Huygens was not sufficiently elaborated for the description of the complexity of such motion. So after invention of the infinitesimal calculus it was possible to consider new problems in mechanics but also in optics in hydrodynamics and so on and to generate the technological instruments for verification of the behavior of the mechanical, optical, hydrodynamical and so on systems. Without such subtle instrument as the infinitesimal calculus was, it was practically no motivation and no inspiration to invent new equipments.

In such a way, the effective development of science consists in the symbiosis of the mathematical instruments with the technology. The symbiosis is so strong that practically there is no possibility for development one of them alone without development of other (Pardy, 1996b).

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